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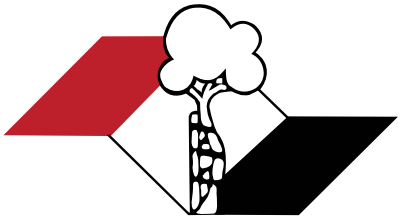

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ACKNOWLEDGEMENTS

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LEVELS OF EVIDENCE FOR PRIMARY RESEARCH QUESTION: Access the following link.

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Levels of Evidence for Primary Research Question[a]

(This chart was adapted from material published by the Centre for Evidence-Based Medicine, Oxford, UK. For more information, please visit www.cebm.net.)

	Types of study			
Level	**Therapeutic Studies Investigating the Results of Treatment**	**Prognostic Studies – Investigating the Effect of a Patient Characteristic on the Outcome of Disease**	**Diagnostic Studies – Investigating a Diagnostic Test**	**Economic and Decision Analyses – Developing an Economic or Decision Model**
I	High quality randomized trial with statistically significant difference or no statistically significant difference but narrow confidence intervals	High quality prospective study[d] (all patients were enrolled at the same point in their disease with ≥80% of enrolled patients)	Testing of previously developed diagnostic criteria on consecutive patients (with universally applied reference ''gold'' standard)	Sensible costs and alternatives; values obtained from many studies; with multiway sensitivity analyses
	Systematic review[b] of Level RCTs (and study results were homogenous[c])	Systematic review[b] of Level I studies	Systematic review[b] of Level I studies	Systematic review[b] of Level I studies
II	Lesser quality RCT (eg, < 80% followup, no blinding, or improper randomization)	Retrospective[f] study	Development of diagnostic criteria on consecutive patients (with universally applied reference ''gold'' standard)	Sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses
	Prospective[d] comparative study[e]	Untreated controls from an RCT	Systematic review[b] of Level II studies	Systematic review[b] of Level II studies
	Systematic review[b] of Level II studies or Level I studies with inconsis tent results	Lesser quality prospective study (eg, patients enrolled at different points in their disease or <80% followup)		
		Systematic review[b] of Level II studies		
III	Case control study[g]	Case control study[g]	Study of non consecutive patients; without consistently applied reference ''gold'' standard	Analyses based on limited alternatives and costs; and poor estimates
	Retrospective[f] comparative study[e]		Systematic review[b] of Level III studies	Systematic review[b] of Level III studies
	Systematic review[b] of Level III studies		Case-control study	
			Poor reference standard	
IV	Case series[h]	Case series		Analyses with no sensitivity analyses
V	Expert opinion	Expert opinion	Expert opinion	Expert opinion

[a] A complete assessment of quality of individual studies requires critical appraisal of all aspects of the study design.
[b] A combination of results from two or more prior studies.
[c] Studies provided consistent results.
[d] Study was started before the first patient enrolled.
[e] Patients treated one way (eg, cemented hip arthroplasty) compared with a group of patients treated in another way (eg, uncemented hip arthroplasty) at the same institution.
[f] The study was started after the first patient enrolled.
[g] Patients identified for the study based on their outcome, called "cases" eg, failed total arthroplasty, are compared with patients who did not have outcome, called ''controls'' eg, successful total hip arthroplasty.
[h] Patients treated one way with no comparison group of patients treated in another way.

SUMMARY

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Original Article

FOOT AND ANKLE

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PEDIATRIC ORTHOPEDICS

ORIGINAL ARTICLE
FOOT AND ANKLE
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RELIABILITY OF WIRELESS INSOLE BAROPODOMETRY OF NORMAL INDIVIDUAL'S GAIT

CONFIABILIDADE DA BAROPODOMETRIA POR PALMILHA SEM FIO NA MARCHA DE INDIVÍDUOS NORMAIS

Larissa Barbosa Oliveira[1,2], *Daniel Augusto Maranho*[1,3], *Alberto Cliquet Júnior*[1], *Mauro Cesar Mattos e Dinato*[1,2], *Rodrigo Gonçalves Pagnano*[1]

1. Universidade Estadual de Campinas, Faculty of Medical Sciences, Department of Orthopedics and Traumatology, Campinas, SP, Brazil.
2. Instituto Vita, São Paulo, SP, Brazil.
3. Hospital Sírio-Libanês, Brasília, DF, Brazil.

ABSTRACT

Objective: The plantar pressure distribution can be assessed quantitatively by computerized baropodometry such as carpet or insole. An insole-type system with wireless transmission was developed and plantar pressure results were previously validated by force platform. However, the reproducibility of the system had not been determined. Our objective was to evaluate the reliability of the results in different gait cycles, clinical characteristics and in different plantar anatomical sites. Methods: 41 healthy adults (age, 34 ± 13 years; body mass index, 25 ± 5 kg/m^2; 26 [63%], male, 26 [63%] practicing physical activity) were evaluated. Baropodometer evaluations were performed in 3 walking cycles with 100 m each, and the reliability between the cycles was examined. Pressure points on the heel, first metatarsal, fifth metatarsal and total plantar pressure were analyzed and compared. Results: Moderate agreement was identified between the second and third cycles (ICC, 0.66; 95% CI, 0.14-0.83). Physical activity practitioners showed higher total plantar pressure (70.8 vs 68.2 Kpa; p = 0.04) and higher pressure in the heel (70.7 vs 68.1 Kpa; p = 0.036) in relation to sedentary ones. Conclusion: The insole was able to assess plant pressure with moderate reliability from the adaptation period. ***Level of Evidence III, Case control study - Investigating a diagnostic test.***

Keywords: Transducers, Pressure. Foot. Monitoring. Gait.

RESUMO

Objetivo: A distribuição da pressão plantar pode ser avaliada quantitativamente por baropodometria computadorizada tipo tapete ou palmilha. Um sistema tipo palmilha com transmissão sem fio foi desenvolvido, cujos resultados de pressão plantar foram previamente validados por plataforma de força. No entanto, a reprodutibilidade do sistema não havia sido determinada. Nosso objetivo foi avaliar a confiabilidade dos resultados em relação a diferentes ciclos de marcha, características clínicas e em diferentes sítios anatômicos plantares. Métodos: Foram avaliados 41 adultos saudáveis (idade, 34 ± 13 anos; índice de massa corpórea, 25 ± 5 kg/m2; 26 [63%], sexo masculino, 26 [63%] praticantes de atividade física). Avaliações com o baropodômetro foram realizadas em 3 ciclos de marcha com distância de 100 m, e avaliada a concordância entre os ciclos. Pontos de pressão no calcanhar, primeiro metatarsal, quinto metatarsal e a pressão plantar total foram analisados e comparados. Resultados: Houve moderada concordância entre o segundo e terceiro ciclos (CCI, 0,66; IC95%, 0,14-0,83). Praticantes de atividades físicas apresentaram pressão plantar total (70,8 vs 68,2 Kpa; p = 0,04) e no calcanhar (70,7 vs 68,1 Kpa; p = 0,036) aumentada em relação aos sedentários. Conclusão: A palmilha foi capaz de avaliar a pressão plantar com confiabilidade moderada a partir do período de adaptação. ***Nível de Evidência III, Estudo diagnóstico - Investigando um teste diagnóstico.***

Descritores: *Transdutores de Pressão. Pé. Monitoramento. Marcha.*

Citation: Oliveira LB, Maranho DA, Cliquet A Jr, Dinato MCM, Pagnano RG. Reliability of wireless insole baropodometry of normal individual's gait. Acta Ortop Bras. [online]. 2021;29(5):238-241. Available from URL: http://www.scielo.br/aob.

INTRODUCTION

The quantification and anatomical monitoring of plantar pressure are important in the practice of the foot and ankle surgeon, as the results can help in the decisions of clinical, surgical and rehabilitation treatments.[1] The evolutionary control of areas of plantar overload allows evaluating individuals over time, and assisting in the preparation of insoles, orthosis and in the indication of surgeries.[2] Additionally, the development of an objective database on plantar pressure and pressure increasing sites can contribute to scientific research in order to observe the best clinical outcome in sports medicine and foot and ankle surgery.[1,3]

Baropodometry quantitatively evaluates plantar pressure and identifies anatomical landmark of overload.[4] The current gold standard in plantar pressure assessment is static and dynamic baropodometry in a

All authors declare no potential conflict of interest related to this article.

The study was conducted at Departamento de Ortopedia e Traumatologia da Faculdade de Ciências Médicas da Universidade Estadual de Campinas.
Correspondence: Larissa Barbosa de Oliveira. Rua Mato Grosso, 306, 1º floor, São Paulo, SP, Brazil, 01239040. laribaroli@gmail.com

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treadmill or platform device.[5] However, the treadmill baropodometer has a relatively high cost and evaluates a single step at a time and may not evaluate the gait performed in the usual way. The mobile baropodometers are coupled in insoles and can be used inside the usual shoes or directly applied to the sole. With advances in sensor technology, portability and versatility, it was allowed that insole baropodometers could be used during gait in a common dynamic way, and during sports in different types of environment.[6,7] With insoles was possible to evaluate plantar pressure under various clinical and research conditions. Nevertheless, validation, reliability or applicability vary between different systems and studies on insole baropodometers.[2,3,6-8] In our field, Varoto et al. developed a wireless plantar pressure monitoring system, with low-cost data acquisition module, coupled with flexible high-resolution sensor.[3] The system was validated with a force platform and a pilot study conducted in a single individual based on static and dynamic activities in the biomechanical platform.[3] However, the reliability of this system in normal individuals had not been studied. The aim of this study was to evaluate the reliability of the results in relation to different gait cycles, clinical variables of volunteers and in different plantar anatomical sites.

MATERIALS AND METHODS

This study was approved by the Research Ethics Committee of the institution (CAAE: 84979417.9.0000.5404). In total, 45 individuals evaluated plantar pressure with the baropodometric insole system. The individuals had no musculoskeletal complaints in the last six months, nor known deformities or diseases in the foot and ankle, lower limbs, hips and spine. Age ranged from 16 to 65 years and the Brazilian numbering of shoes between 37 and 42. Four individuals were excluded due to erratic data acquisition by the system, resulting in the final sample of 41 participants. The mean age (± standard deviation) was 34 ± 13 years, and 26 (63%) were male. The mean height was 1.73 ± 0.09 m; weight, 76 ± 16 kg and body mass index (BMI), 25 ± 5 kg/m^2. The median foot size was shoes number 40. The right side was dominant in 88% of individuals, and 26 (63%) practiced physical activity regularly.

To evaluate plantar pressure, a baropodometer of the insole type was performed. The system consists of a low-cost wireless data acquisition module (less than $20.00), flexible high-resolution pressure sensor (Medical Sensor 3000, Tekscan, Inc., Boston, MA, USA) and *Java* application for visualization.[3] The flexible tactile sensor for measuring pressure distribution consists of two flexible substrates joined by adhesive and dielectric layers. Electrodes of both substrates establish matrix of rows and columns, and each intersection forms detection element that alters electrical resistance when force was applied.[3] The microcontroller associated with the switching circuit selected the detection element, scanning and performing the conversion from analog into digital of voltage amplifier circuits. The switching circuit, including modified voltage dividers, converted electrical resistances into voltage. The generated data was stored in the module (device coupled to the volunteer's leg), and a microcontroller provided serial data via *Bluetooth*® for *Java* application software (Figure 1).[3]

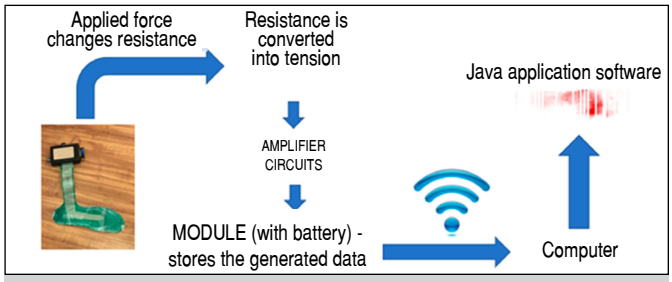

Figure 1. Insole baropometry system demonstration flowchart, developed with wireless transmissibility and low cost components.

For all individuals, the insole was inserted and embedded in the usual sports shoe, in order to avoid interference in gait related to the adaptation of unusual footwear, persisting only individual adaptations secondary to the contact of the foot with the insole. Then, the data acquisition module was fixed to the individual's leg by an elastic band, to make comfortable when walking with the device. A single insole was used by all individuals in all collections. The insole is 26 cm long, choosing to evaluate the feet whose length varied by up to 2 cm (24 to 28 cm, which corresponds, on average, to shoe numbers 37 to 42), so that the insole fits well to the footwear. The insole was calibrated before the beginning of the collections. With the device properly attached to the right foot, the volunteer was asked to climb on the treadmill (Riguetto, model R-2500Ee, Campinas, SP, Brazil) and the acceleration to start the gait was triggered. The first data collection cycle was started at the time the treadmill reached the pre-established speed of 4 km/h, and ceased after the volunteer walked 100 m. Then, two other cycles were collected in the right foot, totaling a distance of 300 m. As the insole is flexible and sensors are present on both sides, the same protocol was performed for the left foot, removing the device after the end of the evaluations.

After data collection and transfer via Bluetooth to the computer, the software created an image in two-dimensional format of the insole, characterized by several points with variable color gradient, corresponding to the pixels generated by the pressure applied at each of the points in the sensor (Figure 2A). Four anatomical regions were visually chosen: head of the first and fifth metatarsal, heel and total plantar surface (all pressure points generated in the extension of the plantar surface at that time). The moments of total contact of the foot with the ground were selected. The pixels responsible for generating the colorimetric gradation of the pressures were obtained by converting the pressure values (kPa) according to the mathematical function $y = -0.9889x + 274.47$. For each volunteer, 242 images were generated per cycle, totaling 726 images for each point (1st MTT, 5th MTT, heel and the whole foot – Figure 2B) in each foot. In a total of 3 cycles, 5.808 points were generated for analysis for each of the volunteers. Each data collection took, on average, 20 minutes.

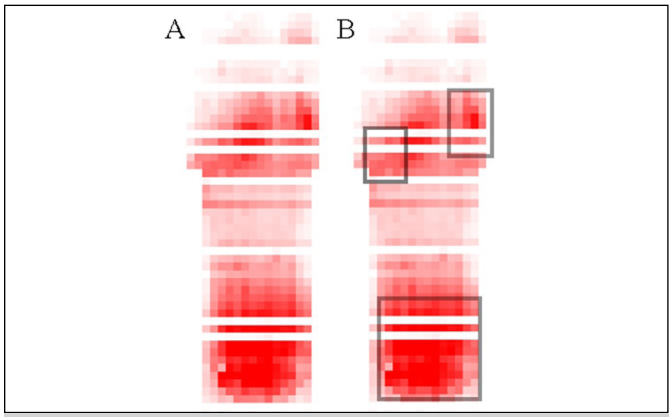

Figure 2. A: Image generated with the foot in medium support; B: Demonstration of selection of the point to be analyzed by the software (in the example we have the selection of the regions of the head of the first and fifth metatarsals and heel).

Statistical Analysis

Demographic data were presented as frequency and percentage, mean and standard deviation, or median. For each pressure point studied, the means of the pressures of the given pathway were obtained, compared to the demographic variables (sex and physical activity) and the analyzed side. The reliability of the instrument was verified by the Intraclass Correlation Coefficient (ICC)[9] between 3

distinct gait sequences from the collections of each individual. The ICC was calculated for each feet, separating the images corresponding to each of the cycles. Thus, we compared the 242 images generated by the pressures of the first 100 m with the 242 images generated by pressures between 101 and 200 m and between 201-300 m. ICC values lower than 0.5 indicate low reproducibility; values between 0.5 and 0.75 indicate moderate reproducibility; values between 0.75 and 0.9 indicate good reproducibility and values greater than 0.9 indicate excellent reproducibility.[9,10] Since it was estimated that the first collection was that of adaptation to the insole, there was potential impairment in relation to reliability when performing the first cycle. Thus, it was decided to perform the statistical analysis of the data of the last collection, that is, between 200-300 m (images 485 to 726). Data normality was verified conducting the Shapiro-Wilk test. Student's t-test or Mann-Whitney test were performed to compare the pressure values between binary variables, and Pearson's coefficient was conducted to evaluate correlation between pressure and BMI values. Statistical analysis was performed with the software *Statistical Package for the Social Sciences* (IBM SPSS Statistics, version 24, IBM Corp., Armonk, N.Y., USA) and $p < 0.05$ values were considered significant.

RESULTS

After the second cycle, the agreement between cycles in baropodometry was moderate. Within the first cycle, the ICC was 0.45 (95% CI, 0.33 to 0.55), corresponding to low reliability. Between the first and second collections (100-200 m; 243-484 images), the ICC was 0.47 (95% CI, 0.34 to 0.57), corresponding to low reliability. Between the second and third collections (200-300 m; 485-726 images), the ICC was 0.66 (moderate reliability; 95% CI, 0.14 to 0.83).

The pressure in the first metatarsal was similar between men and women (69.6 kPa *vs* 69.9 kPa; $p = 0.58$), right and left feet (69.8 kPa *vs* 69.7 kPa; $p = 0.79$), dominant and non-dominant side (69.8 kPa *vs* 69.7 kPa; $p = 0.93$) and physical or sedentary practitioners (70.6 kPa *vs* 68.2 kPa; $p = 0.07$). The pressure in the first metatarsal was similar between men and women (69.6 kPa *vs* 69.9 kPa; $p = 0.69$), right and left feet (69.9 kPa *vs* 69.6 kPa; $p = 0.82$), dominant and non-dominant side (69.9 kPa *vs* 69.6 kPa; $p = 0.30$) and physical or sedentary practitioners (70.6 kPa *vs* 68.2 kPa; $p = 0.06$). The pressure in the calcaneus was similar between men and women (69.7 kPa *vs* 69.9 kPa; $p = 0.71$), right and left feet (69.8 kPa *vs* 69.8 kPa; $p = 0.82$), dominant and non-dominant side (69.8 kPa *vs* 69.8 kPa; $p = 0.28$). However, the pressure in the calcaneus was 3.8% higher in individuals in physical activity practitioners (70.7 kPa) compared to sedentary individuals (68.1 kPa; $p = 0.036$). The plantar pressure was similar between men and women (69.8 kPa *vs* 69.9 kPa; $p = 0.90$), right and left feet (69.8 kPa *vs* 69.9 kPa; $p = 0.88$), dominant and non-dominant side (69.8 kPa *vs* 69.9 kPa; $p = 0.24$). However, total plantar pressure was 3.8% higher among physical activity practitioners (70.8 kPa) compared to sedentary individuals (68.2 kPa; $p = 0.04$).

DISCUSSION

Currently, baropodometry is an important method to assist clinical practice and research in the diseases of the locomotor system.[1] One of the main problems of baropodometry is the low reproducibility and interference of factors that can generate bias, such as sensor technology, spatial system resolution, pressure distribution analysis and calibration procedures.[11] This study evaluated a insole baropodometry system with wireless technology whose results showed that the system is sensitive to evaluate the plantar pressure of normal individuals, with moderate reliability after the initial adaptation session.

A moderate agreement was identified for the insole system developed to measure plantar pressure. When singly considering the first gait cycle in our analysis, i.e., the evaluation of the pressure values generated in the first 100 m (242 images), the agreement assessment was low, probably because it refers to the adaptive cycle to the insole. In the final two cycles, after the adaptation period, we identified an improvement in the agreement and reliability of the measurements. Among the studies performing baropodometers of the insole type, possible difficulties in use and therapeutic application were suggested, in addition to discrepancy of pressure values when compared to other methods of analysis.[2,11] In insoles, exists an adaptation inside the shoes, so it may undergo variations in the pressure distribution secondary to the shape of the base of the footwear, sole and hardness of the external materials.[2] Our results corroborate the findings of Melvin et al.,[12] who suggested that from 166 steps there is accommodation to new footwear and exists an acclimatization distance for dynamic evaluation with insoles.

We identified relative consistency in plantar pressure values in anatomical areas where higher pressure concentrations usually occur. This consistency can be explained by choosing the moment of total contact of the foot with the insole, which represents the medium support phase of the gait in which, theoretically, has regular distribution of pressure along the plantar surface of the foot. Additionally, we applied as inclusion criteria only volunteers with asymptomatic feet, without deformities, metatarsalgia or callosities, which selects individuals with more uniform distribution potential of the pressure on the sole of the foot. The comparison of gait parameters evaluated by platform and insole system, and between insole instrument and platform, showed significantly lower mean values of the peak pressure of the metatarsophalangeal region in insole instruments, using footwear, when compared with the values generated by the platform.[13] This could occur by increasing the contact area inside the shoe, created by the contour of the insole.[14] We did not identify differences in pressure between genders, side or dominance. However, we identified that individuals who practice physical activity have plantar pressure in the heel and whole foot about 4% higher compared to sedentary individuals. This result compares the outcome obtained by Feka et al.,[15] who evaluated the effect of sports practice on static baropodometry. When analyzing 173 women, no significant differences were identified in the areas of plantar surfaces evaluated between the groups of athletes and sedentary.[15] These findings can be explained by the methodology performed, which evaluated a static moment of total contact of the foot with the soil, in which the distribution is considered more uniform. Conversely, existents studies suggests differences in plantar pressure between the variables analyzed, and future studies need to include dynamic evaluation at different times of the gait cycle in order to identify possible pressure differences.[15]

Our study has limitations that must be emphasized. First, we included a small sample of healthy individuals, in which we expected to be no significant hyperpressure points due to the absence of deformities in the feet. Thus, the reliability obtained cannot be extrapolated to pathological situations. Second, variations in the size of the feet may have caused measurement bias in relation to the surface of the insole, which had a unique size for all individuals. Third, we did not evaluate the individuals in platform baropodometry concomitantly to compare the pressure values and accuracy of the insole system. Fourth, a study of kinetics of simultaneous gait was not performed using the insole, making it possible to determine exactly which gait phase corresponded to a certain pressure value. We tried to compensate this limitation by analyzing moments of total contact of the foot in the insole, which theoretically would be equivalent to the medium support in the gait cycle. Fifth, although we evaluated, in theory, areas of higher plantar pressure corresponding to the

head of the first and fifth metatarsals and the heel, the areas were visually selected subjectively by the evaluator. It is worth noting that this insole coupled to a low-cost wireless system is an instrument that is easy to use, lightweight, mobile, capable of recording natural gait in a practical and safe way and with value of correspondence with the power platforms and presenting moderate reliability after the adaptation period.

CONCLUSION

We identified that the flexible and wireless insole baropodometry system was able to evaluate plantar pressure in healthy individuals with moderate reliability from the adaptation period. Future studies are important to establish the clinical applicability and accuracy of the system in physical therapy evaluations and in surgical practice.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article. LBO: search of articles, data analysis and writing of the article, study design and approval of the final article; DAM: study design, data analysis and approval of the final article; ACJ: study design, data analysis and approval of the final article; MCMD: study design, data analysis and approval of the final article; RGP: study design, data analysis and approval of the final article.

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ANALYSIS OF TISSUE BIOPSY AND JOINT ASPIRATION IN THE DIAGNOSIS OF PERIPROSTHETIC HIP INFECTIONS: CROSS-SECTIONAL STUDY

ANÁLISE DA BIÓPSIA DE TECIDOS PERIARTICULARES E DO ASPIRADO ARTICULAR NO DIAGNÓSTICO DE INFECÇÕES PERIPROTÉTICAS DO QUADRIL: ESTUDO TRANSVERSAL

Elton Andreolla[1], *Marco Bernardo Cury Fernandes*[1], *Carla Ormundo Gonçalves Ximenes Lima*[1], *Augusto Carlos Maciel Saraiva*[1]

1. Instituto Nacional de Traumatologia e Ortopedia, Rio de Janeiro, RJ, Brazil.

ABSTRACT

Objective: To evaluate sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of preoperative joint aspiration (PJA) and periarticular tissue percutaneous biopsy (PTPB), as well as their combination, in the diagnosis of infection after total hip arthroplasty. Methods: This cross-sectional study (Level of Evidence II) was conducted with prospective data on 29 patients submitted to PJA with PTPB at the National Institute of Orthopedics and Traumatology from September 2015 to January 2016. Specimens obtained during the procedures underwent microbiological analyses, and the results were compared with those obtained in subsequent revision arthroplasty surgeries. Results: PJA, PTPB, and their combination reached values of 78%, 73%, 89% for sensitivity, respectively; 72%, 90%, 94% for specificity; and 76%, 80%, 90% for accuracy. Conclusions: PJA combined with PTPB was sensitive, specific, and effective in diagnosing periprosthetic hip infection. ***Level of Evidence II, Prospective Cross-Sectional Study***

Keywords: Hip Arthroplasty. Injections, Intra-Articular. Liquid Biopsy. Diagnosis. Infection.

RESUMO

Objetivo: Avaliar a sensibilidade, especificidade, acurácia, valor preditivo positivo e valor preditivo negativo dos métodos diagnósticos aspirado articular pré-operatório (AAPO), biópsia percutânea de tecidos periarticulares (BPTP) e ambos associados na infecção pós-artroplastia total de quadril (IPATQ). Métodos: Trata-se de um estudo transversal (Nível de Evidência II) com coleta prospectiva de dados obtidos de 29 pacientes submetidos a AAPO com BPTP no Instituto Nacional de Ortopedia e Traumatologia durante o período de setembro de 2015 à janeiro de 2016. Foram comparados os resultados das análises microbiológicas dos espécimes obtidos por meio da BPTP e do AAPO com os obtidos intraoperatoriamente nas cirurgias subsequentes de revisão das artroplastias. Resultados: Encontramos uma sensibilidade da AAPO, BPTP e ambos, respectivamente de 78%, 73%, 89%, uma especificidade de 72%, 90%, 94% e uma acurácia de 76%, 80%, 90%. Conclusões: O procedimento de AAPO com BPTP para diagnóstico de infecção periprotética de quadril é sensível, específico e eficaz. ***Nível de Evidência II, Estudo Transversal Prospectivo.***

Descritores: *Artroplastia de Quadril. Injeções Intra-Articulares. Biópsia Líquida. Diagnóstico. Infecção.*

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INTRODUCTION

Infection is a common cause of failure in joint replacement surgery, with 7% to 16% of revision hip arthroplasties (RHA) accounting for it.[1] The incidence of infections after total hip arthroplasty (IATHA) decreased by 1-2% in international reference centers during recent years,[2] but Brazil lacks well-established statistics on this condition.

Many of these infections are hidden, with no active fistula nor obvious clinical signs, presenting as prosthetic loosening, osteolysis, or pain without specific cause.[3]

Thus, an accurate preoperative diagnosis of IATHA is essential in patients with radiological signs of prosthetic loosening and hip pain after arthroplasty.[4] However, diagnosing IATHA in cases without clear signs and active fistulas can be difficult, especially before the lack of a diagnostic method with high specificity and sensitivity.[5] Tests

All authors declare no potential conflict of interest related to this article.

The study was conducted at the Instituto Nacional de Traumatologia e Ortopedia (INTO).
Correspondence: Elton Andreollla. Rua Colombia, 203, sala 01 e 02, Caçador, SC, Brazil, 89500178. elton.a@unochapeco.edu.br

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such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) are indirect markers of infection and/or inflammation, but they have low specificity for the diagnosis of IATHA.[6-8]

Preoperative joint aspiration (PJA) is one of the diagnostic methods for IATHA, with sensibility ranging from 50% to 86% and specificity from 88% to 96.1%.[2,9,10] When associated with periarticular tissue percutaneous biopsy (PTPB) before revision surgery, PJA reaches higher sensitivity (80% to 83%), specificity (90% to 100%), accuracy (97% to 87.9%), and positive predictive values (73.8% to 100%).[5,6] However, some factors limit their diagnostic performance, hindering or even precluding the identification of the causative agent of IATHA, such as prior antibiotic use, biofilm, and the lack of joint fluid.[11]

The test considered gold standard for identifying the pathogen of these infections includes the culture of five or six periprosthetic samples (joint aspirate and tissue fragments) collected during RHA, whereby the presence of two or more positive specimens with isolation of the same infectious agent is considered as IATHA. Most studies addressing PJA and PTPB compare their diagnostic value using this method.[6,11,12]

Up to date, no studies have been conducted in the national scenario investigating the diagnostic value of these two procedures in suspected cases of IATHA. Thus, this study aims to (1) estimate the diagnostic values of PJA, PTPB, and their association, using the culture of articular fluid and tissue fragments extracted during subsequent RHA as gold standard; (2) compare the sensitivity of the PTPB procedure with that of PJA; (3) correlate our results on sensitivity with those reported in other studies; and (4) describe the complications associated with these procedures.

MATERIALS AND METHODS

This is a cross-sectional study conducted with prospective data on patients submitted to PJA with PTPB at the National Institute of Orthopedics and Traumatology (INTO) from September 2015 to January 2016. All patients included in the study had scheduled RHA surgery, either due to aseptic failure or suspected septic failure. Specimens obtained during PJA and PTPB underwent microbiological analyses, and the results were compared with those obtained in subsequent RHA.

Exclusion criteria consisted of (1) acute infection less than four weeks postoperatively; (2) patients who underwent antibiotic therapy within two weeks prior to RHA; (3) patients who did not agree to participate in the study; (4) gross contamination of the collected material; (5) time interval greater than two hours between collection and processing of clinical specimens.

All patients provided written informed consent (ICF) during hospitalization for PJA and BPTP, prior to any of the study procedures. The study was approved by the Research Ethics Committee of the INTO under opinion number 1285647, CAAE 49261115.400005273.

The association between PJA with PTPB is a routine procedure at INTO's Hip Specialized Care Center, involving percutaneous sample collection of joint aspirate and four periprosthetic tissue fragments with the aid of fluoroscopy. This procedure was performed under sterile conditions in the operating room, through the anterolateral route of the hip, using Jamshid needle and with the aid of image intensifier.[13] All patients were submitted to spinal anesthesia.

If no fluid was aspirated, saline solution at 10 mL was instilled in the hip joint and aspirated again – as proposed by Ali et al.[10] and Williams et al.[9] Two specimens of periacetabular periprosthetic tissue and two specimens of femoral periprosthetic tissue were collected. All samples were placed in a sterile tube with fluid thioglycollate medium and referred for analysis at the Laboratory of Anaerobic Biology of the Universidade Federal do Rio de Janeiro (UFRJ) while kept at room temperature, being processed within two hours after collection. Solid specimens received approximately ten sterile glass beads and were submitted to the vortex at 40 Hz for 15 seconds.[14] The resulting pasty material was inoculated in three blood agar plates, supplemented with hemine and menadione (ASS) and chocolate agar. For each medium, one plate was incubated in one type of atmosphere: capnophile (3-5% CO_2 and 12-17% O_2), anaerobiosis (anaerobic jar and/or chamber, containing 10% CO2, 10% hydrogen, and 80% nitrogen) and aerobiosis (35-37°C greenhouse). Moreover, 1 mL of the vortex-resulting material for each specimen was inoculated in anaerobic brain-heart infusion (BHI) medium in an inoculator table. Solid media, thioglycollate, and BHI were observed for 14 days and subcultured in case of liquid medium turbidity. Media presenting no growth after this time were discarded and the culture considered negative.

Bacterial identification was performed using the Matrix Assisted Laser DesorptionIonization - Time of Flight (MALDI-TOF) technology, based on the profile of most abundant proteins specific to each microorganism. One or two recent colonies were applied on a Maldi plate, forming a thin film over which 2 μL of a saturated α-cyano-4-hydroxycinnamic matrix solution (50% acetonitrile, 2.5% trifluoroacetic acid) was deposited. After air-drying, the plate was inserted into the equipment for reading.

During RHA surgery, aspirated joint fluid and four tissue specimens were collected from sites suggestive of periprosthetic infection and submitted to the transport and microbiological analysis procedures described above. After sample collection, positive cases for PJA and PTPB underwent systemic transoperative antibiogram-based antibiotic therapy, whereas those without preoperative positive result underwent antibiotic prophylaxis (cefazolin 2g EV).

Cases presenting growth of the same microorganism in at least two of the five specimens were considered as positive for IATHA, either for those obtained by PJA+PTPB or those obtained during RHA. As supported by Virolainen et al.,[15] cases with bacterial growth in a single specimen were deemed as contamination.

Clinical and demographic data underwent descriptive analysis by calculating median, variation (minimum-maximum), and proportions. Considering the results of the culture of intraoperatively collected samples as gold standard, values of sensitivity (true positive - TP/[TP + false negatives - FN]) and specificity (true negatives - TN)/[false positives - FP + TN]), as well as positive predictive value - PPV (TP/[TP+ FP]) and negative predictive value - NPV (TN/[FN + TN]) of PTPB and PJA were calculated. Diagnostic accuracy was calculated by the sum of TP and TN divided by the number of tests performed. Sensitivity values of PJA used in isolation and combined with PTPB were compared using the McNemar's test. For statistical analysis, 95% confidence intervals and p-values were calculated, with p-values lower than 0.05 being considered significant.

Data were tabulated in the Microsoft Excel (Windows 8 version), and all analyses were performed using SPSS for Windows (version 10.0; SPSS, Chicago, IL, USA).

RESULTS

Of the 32 patients eligible to participate in the study, three were excluded for being using antibiotics at the time of the proposed procedure. Thus, our sample included 29 patients and 30 PJA+PTPB, as one patient underwent the procedure in both hips. Of these, 18 were males (62%) and 11 females (38%) with mean age of 58 years (36–81 range). All patients agreed to participate by signing the informed consent form.

We identified fifteen TP cases, eight TN, three FP, and four FN for PJA. As for PTPB, we verified 14 TP, 10 TN, one FP, and five FN. By assessing the combination of the two procedures (PJA + PTPB), we identified the following:

The diagnostic value of the combined procedure (PJA + BPTP) was higher than that found for each procedure in isolation.

Before the inability of obtaining pure joint fluid, we had to instill saline solution in four cases according to the protocol – none of which corresponded to the false positives and negatives identified among the sample.

According to the criteria described in the methodology section, no tissue or aspirate sample was contaminated in PJA+PTPB or RHA.

We identified 11 different microorganisms in patients who tested positive for infection (Table 1). Except for false positives, microorganisms identified in PJA and PTPB also grew in RHA in positive cases, with the *Staphylococcus haemolyticus* being the most prevalent microorganism in all procedures (21.2%).

Table 1. Microorganisms identified in positive cases of infection after total hip arthroplasty submitted to periarticular tissue percutaneous biopsy, preoperative joint aspiration, and revision hip arthroplasty.

Identified microorganisms
Pseudomonas aeruginosa
Staphylococcus epidermidis
Propionibacterium acnes
Staphylococcus capitis
Staphylococcus haemolyticus
Micrococcusluteus
Acinetobacter baumannii
Klebsiella pneumoniae
Streptococcusgallolyticus
Enterococcus faecium
Enterobacter cloacae

We observed no complications due to PTPB, such as vascular and nerve lesions or needle path infection.

DISCUSSION

As surgical planning differs in the presence of infections, one must rule out infections after total hip arthroplasty (IATHA) before submitting a patient to revision hip arthroplasty (RHA). Moreover, knowing the infective microorganism beforehand allows the surgeon to determine the antibiotic to be added to the prosthetic cement used in the RHA, besides assisting in the decision of performing the revision surgery in one or two stages. When compared to other less effective and noninvasive methods such as inflammatory markers and imaging tests, obtaining periprosthetic specimens in the preoperative period of RHA has gained prominence in the guidelines for diagnosing IATHA. However, the contribution of preoperative joint aspiration (PJA) and periarticular tissue percutaneous biopsy (PTPB) when performed in isolation is still a controversial subject and little studied in the national scenario.

In our study, the PJA + PTPB method showed a sensitivity of 89% – higher than that reported in the literature, ranging from 80% to 83%. The association also presented good specificity (90%), negative predictive value (NPV; 83%), positive predictive value (PPV; 94%), and accuracy (90%). These values are similar to those found in the literature, which show specificity from 94% to 100%, PPV from 74% to 100%, and accuracy from 88% to 97%.[9,12,16] (Table 2).

Table 2. Diagnostic values of the procedures performed.

	PJA	PTPB	PJA+PTPB
Sensitivity (95% CI)	78% (54-93)	73% (48-90)	89% (66-98)
Specificity (95% CI)	72% (39-93)	90% (58-99)	90% (58-99)
PPV (95% CI)	83% (58-96)	93% (68-99)	94% (72-99)
NPV (95% CI)	66% (34-90)	66% (38-88)	83% (51-97)
Accuracy	76%	80%	90%

The higher sensitivity found in our study may be explained by the differentiated microbiological process used, with up to 14 days of incubation period for specimen cultures, rapid transport in culture medium, anaerobic incubation, and the use of the vortex to release bacteria adhered onto biofilm.[7-9,12]

Most studies on PJA and PTPB either do not report incubation period or adopt an unappropriate period, besides waiving the use of vortex in samples processing. According to the literature, culture time should extend for more than seven days in cases of suspected periosteosynthetic infection, and reach up to 14 days in suspected periprosthetic hip infections.[7-9,11,16]

Isolated, PJA reached lower sensitivity, specificity, and accuracy than when combined with PTPB, despite presenting a lower specificity for diagnosing IATHA when compared with isolated PTPB (72% *vs.* 90%). Corroborating the results reported by Fink et al., we found PTPB to show greater sensitivity and accuracy values than PJA.[16] However, our study has some limitations that preclude the interpretation of this finding, such as the lack of histopathological analysis of periprosthetic tissue, global and differential cell count, and leukocyte esterase strip test in the joint fluid – essential resources for the diagnosis of IATHA, especially in cases with negative culture.

Three of the analyzed hips showed the growth of *Propionibacterium acnes*, a pathogen known to present slow growth and low-virulence infections.[17] We were able to identify the growth of this microorganism – which has already proved to be very important in periprosthetic infections – due to the fact that our cultures were incubated by up to 14 days under anaerobic conditions.[12,17]

According to the International Consensus on Periprosthetic Joint Infections (ICPJI),[18] all suspected cases of IATHA must initially undergo synovial fluid analysis, reserving PTPB for inconclusive cases. In this sense, the ICPJI does not recommend the routine use of PTPB for investigating suspected prosthetic infection.

In theory, fine-needle PTPB and PJA involve the same risk for contamination, but while biopsy always obtains periprosthetic tissue, PJA sometimes fail in collecting sufficient material for laboratory analysis. Moreover, isolated PJA does not have good sensitivity to diagnose low-virulent microorganisms such as *Propionibacterium acnes*, verified in this study only by means of PTPB.

Although the literature advises against the use of PTPB in isolation, its sensitivity and accuracy for diagnosing IATHA increases when combined with PJA.[9,18,19] On the other hand, the combination of both methods increase the total time of the procedure – a disadvantage overcame by the benefits offered by the use of PJA + PTPB presented in this article, specially regarding the identification of low-virulent microorganisms that form biofilms.[19]

CONCLUSIONS

PJA combined with PTPB was sensitive, specific, and effective in diagnosing periprosthetic hip infection, thus being an useful and indispensable tool for the proper planning of a revision hip arthroplasty. We expect that further randomized and multicenter studies confirm the findings of this study.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article. EA: writing of the article, review, statistical analysis, surgeries performance, analysis of the intellectual concept of the article, and preparation of the entire research project; MBCF: critical review of the article, analysis, and final approval; COGXL: analysis of the plates, statistical analysis, and idealization of the research project; ACMS: critical review of the article and analysis of intellectual content.

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EVALUATION OF THE RANGE OF MOTION OF A HIP ARTHROPLASTY SYSTEM: A COMPUTER SIMULATION STUDY

AVALIAÇÃO DA AMPLITUDE DE MOVIMENTO DE UM SISTEMA ARTROPLÁSTICO DO QUADRIL: ESTUDO POR SIMULAÇÃO COMPUTACIONAL

Guilherme Guadagnini Falotico[1], *Valéria Romero*[2], *Ricardo Basile*[1], *Edmilson Takehiro Takata*[1]

1. Universidade Federal de São Paulo, São Paulo, SP, Brazil.
2. Universidade Estadual de Campinas, Campinas, SP, Brazil.

ABSTRACT

Objective: To date, the literature lacks consensus on the most efficient method to measure the range of motion of an in vitro prosthetic system. In this study, we propose the use of a relatively low-cost online software to measure the range of motion of hip prosthetic implants manufactured in Brazil and compare its results with the current technical standards for hip arthroplasty. Methods: Three different diameters of femoral heads were evaluated (28 mm, 32 mm, and 36 mm). The mean values of the angular displacement of the prosthesis in each motion axis were obtained by computer simulations. Results: The range of motion with each femoral head was 28mm (extension/flexion: 148°, internal/external rotation: 179°, adduction/abduction: 107°), 32 mm (152°/185°/114°), and 36 mm (158°/193°/120°). Conclusion: The computational method showed that the larger the femoral head, the greater the range of motion of the hip joint prosthetic system. Additional clinical studies are necessary to compare the physical results obtained with the values found in this study by computational modeling. ***Level of evidence V, Experimental study.***

Keywords: Range of Motion, Articular. Total Hip Arthroplasty. Hip Prosthesis.

RESUMO

Objetivo: A maneira mais eficiente de se aferir a amplitude de movimento de um sistema protético in vitro ainda não é bem estabelecido na literatura. Assim, o presente estudo propõe a utilização de um software online de custo relativamente baixo para mensuração da amplitude de movimento de um conjunto protético nacional de quadril e comparar os resultados obtidos com a norma técnica vigente para as artroplastias de quadril. Métodos: A avaliação foi realizada com três diferentes diâmetros de cabeças femorais (28 mm, 32 mm e 36 mm); os valores médios do deslocamento angular da prótese em cada eixo de movimento foram obtidos por meio de simulações computacionais no programa Autodesk Inventor. Resultados: as amplitudes de movimento obtidas foram: cabeça 28mm (extensão/flexão: 148°, rotação interna/externa: 179°, adução/abdução: 107°), cabeça 32° (152°/185°/114°), cabeça 36° (158°/193°/120°). Conclusão: O método computacional utilizado no presente estudo possibilitou concluir que quanto maior a cabeça femoral, maior será a amplitude de movimento do sistema protético para articulação de quadril. Novos estudos clínicos, tanto pré quanto pós-operatórios, devem ser realizados para comparar os resultados físicos obtidos com os valores encontrados nesta avaliação por meio de modelo computacional. ***Nível de Evidência V, Estudo experimental.***

Descritores: *Amplitude de Movimento Articular. Artroplastia Total de Quadril. Prótese de Quadril.*

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INTRODUCTION

Prosthetic instability is one of the main indications for hip revision surgery, representing approximately 21% of revision surgical procedures.[1] In addition, acetabular malposition is recognized as the main factor for prosthetic dislocation. However, dislocation episodes occur even when hip arthroplasties are placed in the Lewinnek safe zone.[2] The impingement between the femoral and acetabulum components is an important mechanism causing dislocation in supposedly well-positioned prostheses. Marchetti et al. demonstrated in a clinical study of prostheses that underwent revision that 80% of the prostheses removed due to instability had macroscopic signs of impingement between the prosthetic elements.[3] Contact between components is also related to wear, loosening, and early failure of arthroplasty.[4] Thus, the construction of a prosthetic hip without impact between its components is essential for the long-term success of the surgery.

All authors declare no potential conflict of interest related to this article.

The study was conducted at Departamento de Ortopedia e Traumatologia da Universidade Federal de São Paulo.
Correspondence: Guilherme Guadagnini Falotico. Rua Napoleão de Barros, 715, Vila Clementino, São Paulo, SP, Brazil, 04024002. ggfalotico@yahoo.com.br

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To obtain an impingement-free arthroplasty, besides the good positioning of the components, an increase in the range of motion of the prosthetic system must be sought. This is most commonly achieved by increasing the diameter of the prosthetic femoral head (> 28 mm).[5] However, the most efficient way to measure the range of motion of a prosthetic system is not well established in the literature.[6-8]

In this study, we propose the use of a simple and relatively low-cost online software to measure the range of motion of a hip prosthetic manufactured in Brazil and compare the results obtained with the values established by the regulations for hip prosthetic implants.[9]

MATERIALS AND METHODS

The evaluation was performed with Taper femoral prosthesis and Phenom Poly II acetabulum (Víncula, Brazil) with three different femoral head diameters (28mm, 32mm, and 36mm); the mean values of the angular displacement of the prosthesis in each axis of movement (flexion/extension, abduction/adduction, and internal/external rotation) (Figures 1, 2, and 3) were obtained through computer simulations in the Autodesk Inventor® software. All evaluation parameters were based on the normative document "ISO 21535:2007 Non-active surgical implants – Joint replacement implants – Specific requirements for hip-joint replacement implants".[9] We limited the movements to simulate the collision between the components. We analyzed the overlaps using the software solver called Contact Set, making sure that all components were within the limits pre-established by the technical standard for prosthetic implants.

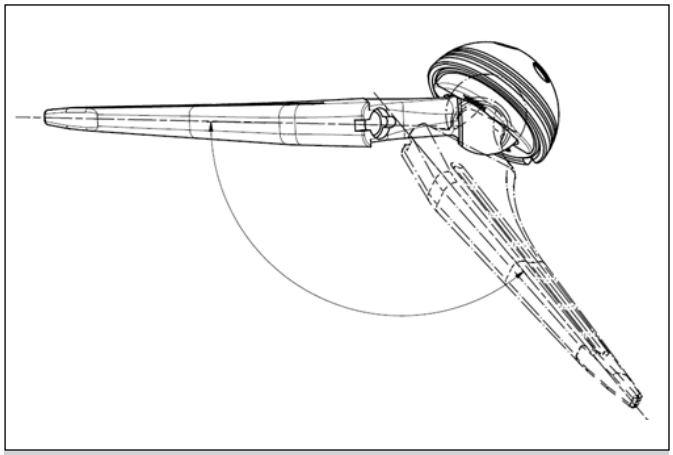

Figure 1. Flexion/Extension Movement.

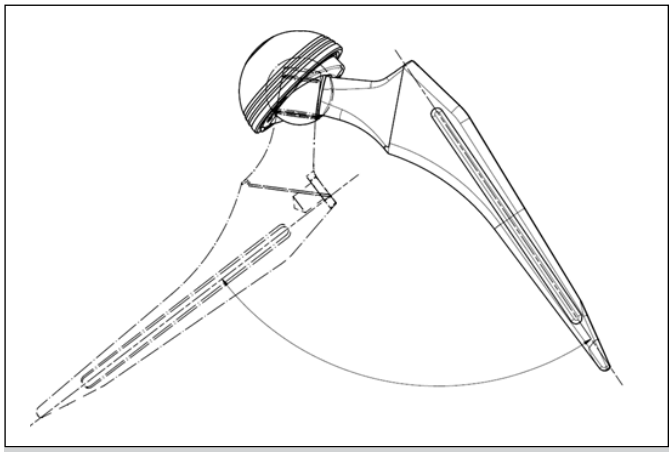

Figure 2. Abduction/Adduction Movement.

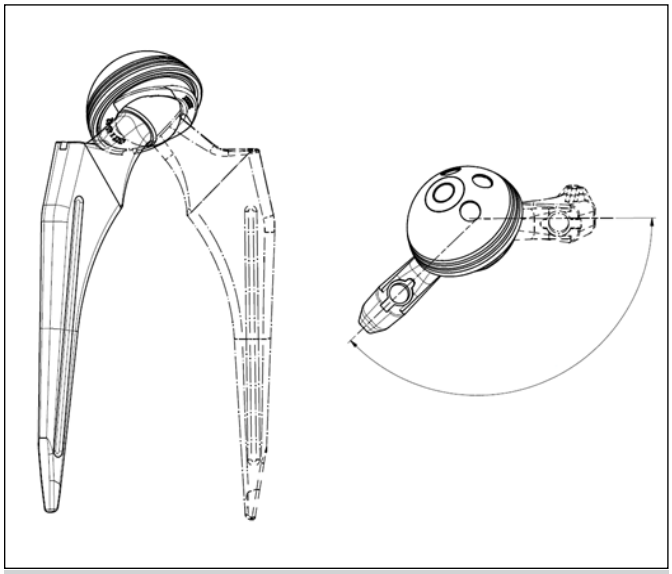

Figure 3. Internal/External Rotation Movement.

We simulated the components under the "worst-case" scenario, in which the smallest ranges of motion are recorded. The criterion for choosing the prosthetic was based on a geometric evaluation of the system; different sizes of femoral heads were included and combined with a polyethylene acetabular insert with a 10º edge, as this insert has the shortest impingement-free angular path.

The implants were positioned according to the Lewinnek safe zone,[10] described as follows:

- The acetabulum is positioned at 45° to the sagittal plane and 15° to the frontal plane;
- The femoral component performed the simulations in the 3 planes of motion.

Following ISO 21535, of 2008,[11] the values that define adequate prosthetic functioning must be greater than or equal to the following total arc of motions: 100° for flexion/extension movements; 60° for abduction/adduction movements, and 90° for internal/external rotation.

RESULTS

The different diameters of the femoral heads observed in the range of motion assessment tests for the Brazilian prosthetic system for the hip joint were: head 28 mm (extension/flexion: 148°, internal/external rotation: 179°, adduction/abduction: 107°), head 32° (extension/flexion: 152°, internal/external rotation: 185°, adduction/abduction: 114°), head 36° (extension/flexion: 158°, internal/external rotation: 193°, adduction/ abduction: 120°) (Table 1).

Table 1. Comparison of the different diameters of the femoral heads observed in the hip prostheses ranges of motion assessment tests and normative values.

Movements	Normative Requirements (degrees˚)¤	28˚ mm head p = 0.023	32˚ mm head p = 0.020¤	36˚ mm head p = 0.018¤
Flexion/ Extension ¤	100˚¤	148˚¤	152˚¤	158˚¤
Abduction/ Adduction ¤	60˚¤	107˚¤	114˚¤	120˚¤
Internal/ External Rotation ¤	90˚¤	179˚¤	185˚¤	193˚¤

We found a statistically significant difference in the range of motion of the prosthesis with a 28 mm head compared to the set with a 32 mm head ($p = 0.011$), in the analysis of 28 × 36 mm ($p = 0.004$) and 32 × 36 mm ($p = 0.004$).
Paired values were compared using Student's t-test, considering a 5% significance level.

DISCUSSION

The results obtained through computational analysis in the Autodesk Inventor® software are compatible with other evaluation methods of the prosthetic range of motion described in the literature. In addition, the angulation values were higher when compared to the range of motion values established by the normative instruction "ISO/ABNT 21535:2018" (extension/flexion: 100°, internal/external rotation: 90°, adduction/abduction: 60°). Thus, the use of a simple and relatively low-cost online tool can be applied in clinical practice in patients in the postoperative period of total hip arthroplasty for a range of hip movements, as well as in the preoperative period to find the best positioning of the prosthesis for each patient.
In 2008, Kiguchi et al.[12] evaluated the dislocation of a prosthetic system using a hip movement simulator with 26, 32, and 40 mm heads and concluded that uncoupling occurred earlier with 26 mm heads. However, this experimental study performed only a descriptive analysis of the angle values.[12]
Bunn, Colwell Jr and D'Lima[13] in 2014 developed a computer model based on tomographic images to assess the influence of the diameter of the prosthetic femoral head on the risk of post-operative dislocation and concluded that the risk of impingement and dislocation was lower for larger heads. The disadvantage of the method is the need to expose the patient to radiation to capture the images.[13]
McCarthy et al.[14] in 2016 analyzed 10 patients in flexion positions considered to be at risk for posterior hip dislocation (standing from a low chair, and squatting and picking up an object on the ground). Movement markers were placed in the anterosuperior iliac spine and sacrum and the movement of the femur in relation to the pelvis was recorded (flexion-extension, adduction-abduction, and medial and lateral rotation). The results were extrapolated for computational biomechanical analysis and all components were within the prosthetic Lewinnek's safe zone. During the squat, 8 out of 10 prosthetic hips had impingement, and impingement occurred in 9 of the 10 prostheses when picking up an object on the ground. All patients had a 36 mm femoral head. Thus, the study concluded that even with a larger diameter femoral head and the prosthesis in a safe zone, extreme amplitude activities can lead to prosthetic impact and increase the dislocation risk.[14]
Gu et.al.[15] in 2019 developed an impact analytical model to establish the ideal specific positioning of the prosthesis for each patient during the preoperative period. The model was created through mathematical calculations and associated computer simulation and allows to demonstrate the impact-free areas (green) and the risk areas (red) with an accuracy of ± 1.4°.[15] Despite being very promising, its clinical applicability is not feasible due to its high cost and lack of access to this system in Brazil.
A major limitation of this study is its experimental nature, and the behavior of the prosthetic set in vivo may result in angular values different from those found, due to each patient's specific capsule-ligament anatomy. However, the use of simple low-cost software was consistent with other models in the literature and with the established technical standards, opening up the possibility of improving preoperative planning, making it more suitable for each patient, and improving the assessment of patients with prosthetic instability.

CONCLUSION

The computational method used in this study allowed us to conclude that the larger the femoral head, the greater the range of motion of the prosthetic system for the hip joint, with values within the technical standards recommended in Brazil. New clinical studies are required to compare the physical results obtained with the results found in this computational model.

AUTHOR'S CONTRIBUTION: Each author contributed individually and significantly to the development of this article. GGF: writing and statistical analysis; VR: project idealization and text revision; RB: computer simulations; ETT: project idealization and supervision of all stages of the project.

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ANATOMICAL STUDY OF THE POSTEROLATERAL LIGAMENT COMPLEX OF THE KNEE: LCL AND POPLITEUS TENDON

ESTUDO ANATÔMICO DO COMPLEXO LIGAMENTAR POSTEROLATERAL DO JOELHO: LCL E TENDÃO POPLÍTEO

Marcel Faraco Sobrado[1,2], Camilo Partezani Helito[1,2], Lucas da Ponte Melo[1], Andre Marangoni Asperti[1], Riccardo Gomes Gobbi[1], Fabio Janson Angelini[1]

1. Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, SP, Brazil.
2. Hospital Sírio Libanês, São Paulo, SP, Brazil.

ABSTRACT

Objective: To analyse the distances between the femoral insertions of the popliteus tendon (PT) and the lateral collateral ligament (LCL) through dissections of cadaveric specimens in a mixed population. Methods: Fresh cadavers were dissected, and the anthropometric data of all specimens were recorded. The distances from the origin of the PT to the LCL in the femoral region and the diameter of each structure were measured using a digital calliper. Results: In total, 11 unpaired knees were dissected, eight men and three women, with an average age of 71.5 ± 15.2 years, weight of 57.2 ± 15.6 kg, and a mean height of 170.5 ± 8.2 cm. The distance from the center of the femoral footprint of the LCL to the PT was 10.0 ± 2.4 mm. The distances between the edges closest to each other and those more distant from each other were 3.1 ± 1.1 mm and 16.3 ± 2.4 mm, respectively. Conclusion: The distance between the midpoints of the PT and the LCL in our mixed population is smaller than the distances often reported in the literature. PLC reconstruction with separate tunnels for the LCL and PT may not be technically possible for individuals of any population. ***Level of Evidence III, Diagnostic studies.***

Keywords: Knee. Knee Dislocation. Tendons. Knee Injuries.

RESUMO

Objetivo: Analisar as distâncias entre as inserções femorais do tendão poplíteo (TP) e o ligamento colateral lateral (LCL) através de dissecções de espécimes cadavéricos em uma população miscigenada. Métodos: Cadáveres frescos foram dissecados. Foram registrados dados antropométricos e foi avaliada a distância da origem do TP e do LCL na região femoral com auxílio de paquímetro digital. Foi também avaliado o diâmetro do footprint femoral do TP e do LCL. Resultados: Foram dissecados 11 joelhos não pareados, 8 homens e 3 mulheres com uma idade média de 71,5 ± 15,2 anos, pesando em média 57,2 ± 15,6 kgs e com altura de 170,5 ± 8,2 cm. A distância do centro do footprint femoral do LCL e do TP foi de 10,0 ± 2,4 mm. As distâncias das bordas mais próximas entre si e das mais distantes entre si foram de 3,1 ± 1,1 mm e 16,3 ± 2,4 mm, respectivamente. Conclusão: A distância entre o ponto central do TP e do LCL em nossa população mais miscigenada demonstrou um valor absoluto menor do que é, frequentemente, relatado na literatura. Uma reconstrução ligamentar do CPL com túneis separados para o LCL e o TP pode não ser tecnicamente possível para indivíduos de qualquer população. ***Nível de Evidência III, Estudos diagnósticos.***

Descritores: *Joelho. Luxação do Joelho. Tendões. Traumatismos do Joelho.*

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INTRODUCTION

Once considered rare, lesions of the posterolateral ligament complex (PLC) may be present in up to 16% of knee ligament injuries.[1] Non-recognition of these lesions and their inadequate treatment are associated with residual instability and failure in reconstruction of the anterior and posterior cruciate ligaments.[2,3] Knowledge about the anatomy and biomechanics of the knee PLC has increased in recent years. Adequate identification of anatomical structures is essential for correct treatment of ligament injuries of the knee. Existing reconstruction techniques are diverse and classified as anatomical or non-anatomical.[4-6] Some of these techniques do not include reconstruction of the popliteus tendon (PT), although recent studies have shown the biomechanical importance of the PT and the popliteofibular ligament to the posterolateral stability of the knee.[7,8] As a result, surgeons tend to use surgical techniques that reproduce the anatomical insertions of the structures, especially the insertions of the PT and the lateral collateral ligament (LCL) in the femur.

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The study was conducted at the Institute of Orthopedics and Traumatology of Hospital das Clínicas of the Medical School of Universidade de São Paulo.
Correspondence: Marcel F. Sobrado. Rua Dr. Ovídio Pires de Campos, 333, São Paulo, SP, Brazil, 05403010. marcel.sobrado@usp.br

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To construct the femoral tunnels of the LCL and PT, some authors recommend constructing two separate tunnels, whereas others prefer using a single femoral tunnel from which the two structures originate.[5,7,9-11] One of the main studies on the anatomy of the PLC of the knee found a mean distance of 18.5 mm (16.8-22.9 mm) between the midpoint of the normal anatomical insertion of the PT and the LCL in 10 cadavers,[12] and this parameter is currently considered the gold standard in cases of anatomical reconstruction of the PLC. However, knee dimensions vary significantly according to ethnicity and biotype, and, for example, the knees of North American and Caucasian populations are generally larger.[13-16] Thus, using a distance of 18.5 mm between the femoral insertions of the PT and the LCL may not be adequate for anatomical reconstruction of the PLC in smaller knees. Constructing tunnels that are very close to each other, i.e., with less than 2 mm of bone bridge, to reproduce the exact anatomical origins of the LCL and PT, can lead to surgical complications such as tunnel confluence, graft fixation failure, and subsequent instability and failed ligament reconstruction,[17,18] especially when multiple femoral tunnels are used in cases of multiligament lesions.

Thus, the primary objective of this study is to analyse the distances between the femoral insertions of the PT and the LCL through dissections of cadaveric specimens in a mixed non-Caucasian population to assess whether the distances are comparable to findings in the literature.

MATERIALS AND METHODS

Fresh unpaired cadavers from our institution were dissected. Approval was obtained from the institutional scientific committee and the Ethics Committee for the Analysis of Hospital Research Projects. Anatomic dissections were performed according to the availability of cadavers from January to May 2019. All specimens had information on age, weight, and height.

The exclusion criteria for anatomical evaluation were cadavers with total knee arthroplasty, fractures of the distal third of the femur, anterior peripheral lateral ligament reconstruction, and a history of joint infection.

The distance between the midpoints of the PT and LCL origins in the lateral region of the femoral condyle was measured using a digital calliper (150 mm DC-60 Western, Zhejiang, China) with a precision of 0.01 mm. (Figure 1) For these structures, measurements of the edge points most distant from each other and those closest to each other and the diameters at the largest axis of the femoral insertions of the PT and LCL were also performed.

Anatomical dissections were performed in planes starting with the skin and subcutaneous tissue, followed by tenotomy of the quadriceps tendon in the myotendinous junction. Then, medial parapatellar access was established to open the retinaculum and resect the insertion of the patellar ligament in the anterior tuberosity of the tibia by detaching soft tissues or osteotomy of a small bone fragment.

The posterior portion of the retropatellar fat was removed for better visualization of the region. The iliotibial tract was detached from Gerdy's tubercle, and tenotomy of the biceps tendon and detachment of the lateral gastrocnemius were performed. The PT and LCL were carefully dissected and isolated, and the distances from the midpoints, the proximal edges, and the most distal edges to the femoral origins of these two structures, were measured with the knee in 90° flexion.

The measurements were performed by two examiners after dissection of the specimens, and correlation tests were performed between the examiners. Inter-rater reliability was assessed using Cohen's kappa coefficient. The level of agreement was classified according to McHugh: none (0-.20), minimal (.21-.39), weak (.40-.59), moderate (.60-.79), strong (.80-.90), and almost perfect (> .9).[19]

RESULTS

In total, 11 knees from eight men and three women with an average age of 71.5 ± 15.2 years, an average weight of 57.2 ± 15.6 kg, and a mean height of 170.5 ± 8.2 cm were dissected.

The distance between the midpoints of the femoral origins of the LCL and PT was 10.0 ± 2.4 mm. The distances between the edges closest to each other and those more distant from each other were 3.1 ± 1.1 mm and 16.3 ± 2.4 mm, respectively. The mean maximum diameter of the PT was 7.9 ± 2.1 mm, and the mean maximum diameter of the LCL was 7.3 ± 2.1 mm (Table 1 and Figure 1).

Figure 1. Dissection of the posterolateral complex and identification of the LCL and PT.

Table 1. Dissected specimens.

					Distances (mm)			Femoral insertion (mm)	
Specimens	**Gender**	**Age**	**Weight (kg)**	**Height (cm)**	**Closest edges**	**Midpoints**	**Distant edges**	**Popliteus**	**LCL**
1	Male	84	50.0	162.0	4.22	9.69	14.81	5.00	4.87
2	Male	91	64.0	162.0	4.50	12.71	19.08	6.96	5.14
3	Male	76	60.0	170.0	4.08	8.30	13.72	7.22	5.72
4	Male	74	98.0	181.0	3.10	11.54	18.84	12.07	8.04
5	Female	84	40.0	165.0	4.30	15.28	19.25	7.77	11.98
6	Male	61	45.0	169.0	1.54	7.61	13.30	7.09	6.12
7	Female	85	55.0	160.0	1.85	7.83	12.58	5.40	6.88
8	Female	43	55.0	175.0	3.33	7.82	17.43	10.40	8.40
9	Male	50	45.4	177.0	1.78	10.71	16.93	9.19	8.97
10	Male	71	64.0	185.0	2.39	10.00	17.59	7.12	5.91
11	Male	67	53.0	170.0	2.16	8.83	16.71	9.26	8.84
Average		**71.5**	**57.2**	**170.5**	**3.11**	**10.03**	**16.39**	**7.95**	**7.35**
SD		**15.2**	**15.6**	**8.2**	**1.13**	**2.40**	**2.41**	**2.11**	**2.13**

The agreement between the examiners was considered strong (kappa 0.86; p < .001).

DISCUSSION

The main finding of this study is that the distance between the midpoints of the PT and the LCL was shorter than the distances frequently reported in the literature. The value of 10.0 ± 2.4 mm is significantly shorter than the previously published distance of 18.5 mm in another dissection series.[12] This finding is very interesting because a surgical technique involving tunnels separated by a distance of 18.5 mm for the LCL and PT does not, necessarily, reproduce more accurately the anatomy of individuals of any population.

The distances and absolute sizes of the knee ligament structures, such as the anterior cruciate ligament, have been directly correlated with the sizes of the lateral femoral wall in the intercondylar notch, the tibial plateau, and femoral and tibial lengths.[20,21] Our study population had an average height of 170.5 ± 8.2 cm, which is comparable to the mean heights of populations in South America and several countries worldwide. Notably, the mean population height varies significantly among countries and can reach values greater than 180 cm for men in European countries such as the Netherlands and approximately 155 cm for women in India.[22] The mean height of the population in our study, which is more mixed, may not be similar to the mean height of Caucasian individuals in other studies evaluating posterolateral complex, who tend to be taller. Unfortunately, information regarding the heights of dissected specimens was not reported in other studies, thus complicating comparisons.

Anatomical differences in the knee between different populations have been demonstrated for unicompartmental prostheses. In an anthropometric study of the medial tibial plateau, Surendran et al.[23] showed that the design of unicondylar arthroplasty developed for Caucasians would be inadequate for the Korean population. Similar studies have been published for Chinese and Turkish populations reinforcing the significance of ethnic anatomical differences.[24,25]

The influence of age on the sizes of anatomical structures is also controversial. Although ligaments and tendons naturally degenerate with age, the sizes of these structures seem to be related to individual bone morphology dimensions. Iriuchishima et al.[26] evaluated the effect of age on the cross-sectional area of the anterior cruciate ligament in the axial and sagittal planes, and did not find a significant difference when the values were normalized to the length of the Blumensaat line. The specimens in our study were aged 71.5 ± 15.2 years and were part of the regional mortality information system, with deaths resulting from natural causes. To our knowledge, no studies have demonstrated that old age can modify, increase, or reduce the footprints of the structures studied.

Moreover, the distance of 10.0 ± 2.4 mm between the midpoints of the LCL and PT and its impact on the risk of tunnel confluence must be emphasized when performing ligament reconstruction. In our study, the PT and LCL had mean diameters of 7.9 mm and 7.3 mm, respectively, at their femoral insertions. For ligament reconstruction with the use of two separate grafts measuring approximately 8 mm, two separate 8-mm tunnels would need to be created for these grafts. In a knee with a 10 mm distance between the LCL and PT insertions, we would need a bone wall of only 2 mm between the tunnels, increasing the risk of confluence, which is a worrisome complication in these cases. (Figure 2) Furthermore, in our study, the distance between the midpoints of these footprints was shorter than 10 mm in six (54.5%) knees, which would result in tunnel confluence if we used this value for the tunnel diameters.

Figure 2. Ligament reconstruction with the use of two separate grafts for the LCL and PT.

The risk of injury to other structures during tunnel creation in the lateral cortical surface of the femur is a complication described by Helito et al. for the anterolateral ligament (ALL). The risk of iatrogenic LCL injury due to an ALL tunnel with a 10-mm diameter can reach 40%.[27] In addition to the risk of confluence of the PT and LCL tunnels during ligament reconstruction, when we increase the distance between the tunnels to maintain an adequate bone bridge, we incur the risk of injury to other structures such as the ALL.

A common situation that increases technical and surgical difficulty is ACL injury associated with the posterolateral corner. In this situation, three tunnels in the lateral femoral condyle are required for the LCL, PT, and ACL, increasing the risk of local complications. An alternative strategy to avoid this type of problem would be the use of a single-tunnel technique for the PT and LCL as described by Angelini et al., who reported good clinical results.[10,11] For this technique, with the knee flexed, the authors recommend positioning the graft of the PT at the most anterior wall inside the femoral tunnel and the LCL graft in most posterior wall. Then, an interference screw is placed between the two tendons to reproduce the anatomical positions of these two structures.

The excellent work reported by LaPrade et al. showed the anatomy of the PLC of the knee in detail and provided a deep understanding of the spatial relationships among the structures of this region, allowing more precise development of surgical techniques considered more consistent with the knee anatomy and emphasizing the importance of reconstruction of the LCL, PT, and popliteofibular ligament. Notably, however, significant differences exist among populations from different countries. Studies comparing miscegenation in South American countries and the United States have reported a miscegenation rate of up to 50% for Brazil and values lower than 20% for North America. In China, these values are less than 5%.[28,29]

Therefore, the results in our study do not necessarily contradict those of previous studies; however, they suggest that regional differences may exist between populations, reinforcing the importance of an individualized evaluation for the treatment of each patient.

CONCLUSION

The distance between the midpoints of the PT and LCL showed a lower absolute value than the distances often reported in the literature. The value of 10.0 ± 2.4 mm is significantly lower than previously published values. Ligament reconstruction with separate tunnels for the LCL and PT may not be technically possible for individuals of any population.

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QUANTIFICATION OF NEURAL ELEMENTS IN POSTERIOR CRUCIATE LIGAMENT: COMPARISON BETWEEN HEALTHY KNEES AND WITH PRIMARY OSTEOARTHROSIS

QUANTIFICAÇÃO DOS ELEMENTOS NEURAIS NO LIGAMENTO CRUZADO POSTERIOR: COMPARAÇÃO ENTRE JOELHOS HÍGIDOS E COM OSTEOARTROSE PRIMÁRIA

Marcelo Parente Oliveira[1], *Roberto José Vieira de Mello*[2], *Luciano Tavares Montenegro*[2], *Silvania Tavares Paz*[2], *Diego Ariel de Lima*[3], *José Alberto Dias Leite*[4]

1. Federal University of Cariri, Faculty of Medicine, Barbalha, CE, Brazil.
2. Federal University of Pernambuco, Department of Pathology, Recife, PE, Brazil.
3. Federal Rural University of the Semi-Arid Region, Mossoró, RN, Brazil.
4. Federal University of Ceará, Department of Surgery, Fortaleza, CE, Brazil.

ABSTRACT

Objective: To quantify the neural elements in the posterior cruciate ligament (PCL) in healthy knees and with primary osteoarthrosis (OA). Methods: In two groups with OA, one of cadavers and another of individuals, the area of neural elements identified in histological sections of PCL with anti-S100 immunohistochemistry was quantified. Results: The overall mean area of the neural elements was 0.96% ± 0.67%, with the value in the cadaver group of 1.02% ± 0.67% and in the OA group of 0.80% ± 0.64%, with a significant statistically difference (p = 0.001). No correlation was observed between neural element quantification and the age of the individuals (p > 0.05). There was no difference in the quantification of neural elements between the sexes in the cadaver group (p = 0.766), but in the OA group there was a statistically significant reduction in males (p = 0.003). Also, in the osteoarthrosis group there was no difference in the quantification of neural elements in the knees with varus or valgus alignment (p = 0.847). Conclusion: There was a decrease in neural element quantification in PCL of individuals affected by OA in relation to non-arthritic individuals, with this quantification not related to age or with the axis of the lower limb. However, this quantification is not related to age or the axis of the lower limb. ***Level of Evidence III, Case control study.***

Keywords: Posterior Cruciate Ligament. Mechanoreceptors. Nerve Tissue. Immunohistochemistry. Osteoarthritis.

RESUMO

Objetivo: Quantificar os elementos neurais no ligamento cruzado posterior (LCP) em joelhos hígidos e com osteoartrose primária (OA). Métodos: Em um grupo de cadáveres e outro de indivíduos com ao, foi realizada a quantificação da área dos elementos neurais identificados em cortes histológicos do LCP com imunohistoquímica anti-S100. Resultados: A média geral da área dos elementos neurais foi 0,96% ± 0,67%, com o valor no grupo cadáver de 1,02% ± 0,67% e no grupo OA de 0,80% ± 0,64%, havendo uma diferença estatisticamente significante (p = 0,001). Não se observou correlação entre a quantificação dos elementos neurais e a idade dos indivíduos (p > 0,05). Não se observou diferença na quantificação dos elementos neurais entre os sexos no grupo cadáver (p = 0,766), mas no grupo OA se observou redução estatisticamente significante no sexo masculino (p = 0,003). No grupo OA não houve diferença na quantificação dos elementos neurais nos joelhos com alinhamento varo ou valgo (p = 0,847). Conclusão: Foi demonstrada uma redução na quantificação dos elementos neurais no LCP de indivíduos acometidos por OA em relação aos indivíduos não artrósicos, com essa quantificação não tendo relação com idade nem com o eixo do membro inferior. ***Nível de evidência III, Estudo de caso controle.***

Descritores: *Ligamento Cruzado Posterior. Mecanorreceptores. Tecido Neural. Imuno-Histoquímica. Osteoartrose.*

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INTRODUCTION

Mechanoreceptors are responsible for detecting the deformation of periarticular tissues and for the sensory coding of signals that inform about intrinsic and extrinsic joint forces. These signals offer the cognitive perception of the strength, positioning, movement, speed and direction to which the joint is submitted, contributing indispensablely to joint homeotasis.[1-3]

All authors declare no potential conflict of interest related to this article.

The study was conducted at the Federal University of Ceará.
Correspondence: Marcelo Parente Oliveira. Rua Divino Salvador, 284, Rosário, Barbalha, CE, Brazil, 63180000. marceloparente03@hotmail.com

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Osteoarthrosis (OA) is marked by capsuloligamentous laxity, loss of articular cartilage, bone deformity and limb misalignment, factors that strongly influence the loss of proprioceptive sensitivity. It is also observed the decline in proprioceptive capacity with the aging process, which also has an important relevance when observing the degenerative joint disease, characteristically incident in older age groups.[1,4] The joint replacement through arthroplasty has led to proprioceptive sensitivity at an intermediate level between the disease status and the normal, with the objective of restoring limb alignment, soft tissue balance and joint stability. The knees with more accurate proprioceptive capacity may be related to the load applied more physiologically, which is important in preventing the loosening and the wearing of arthroplasty implants.[4-6]

Several studies examined the difference in proprioceptive capacity after the total knee arthroplasty (TKA) and compared the results of several joint reconstruction techniques, particularly the preservation or not of the posterior cruciate ligament (PCL), among other reasons, for believing that this structure has an important proprioceptive function,[4-6] being demonstrated and studied the mechanoreceptors in the posterior cruciate ligament of the knee.[2,3,7-12] However, benefits with the preservation of PCL have not been consistently observed. This may be related to a reduction in the population of mechanoreceptors with the advancing age and even faster in OA.[2,8,11,13,14]

The aim of this study was to analyze the neural elements in PCL and to verify whether there is; a reduction in the quantification of neural elements in OA; a correlation with the age of the individuals investigated exists; a difference between males and females; and a difference between arthritic knees with varus or valgus alignment.

MATERIALS AND METHODS

This study, developed from July 2017 to December 2019, was conducted in accordance with the Helsinki Declaration of 1995, and was analyzed and approved by the Research Ethics Committee of the Medical School of Universiade Federal do Cariri (UFCA) (CAAE: 31115014.9.0000.5035). Two groups of individuals were studied, one consisting of fresh cadavers and another by patients with primary knee OA. All individuals studied or their legal guardians signed a Free and Informed Consent Form.

In the cadaver group, both sexes were included, with no age restrictions, and 24 PCLs of 24 cadavers with no morbid past in the joint were studied. The knee side was chosen by drawing lots. Macroscopic examination of the joint, as well as the medical, cadaveric and interrogation reports to family members or guardians were evaluated to make sure that there were no previous knee injuries. Cadavers with history or evidence of previous morbidity, inflammatory diseases and surgical past in the joint were excluded. The cadaver was positioned in ventral decubitus and through a posterior access to the knee, and the PCL was collected from the femoral insertion until the tibial insertion.

In the OA group, both sexes were included, with no age restrictions, and 14 PCLs of patients with primary OA, submitted to TKA with posterior stabilization, were studied. Patients with secondary OA and previous knee surgery were excluded. For collection during the TKA surgical procedure, after medial parapatellar arthrotomy and lateral dislocation of the patella, with the knee at maximum flexion, the osteophytes and anterior cruciate ligament (ACL) were resected, when present in the femoral intercondylar, the anteriorization of the tibia under the femur and proximal tibial cut, allowing the collection of PCL from its femoral insertion to tibial insertion.

The preliminary study with hematoxylin-eosin (HE) staining showed in all specimens evaluated ligament tissue with fibers and typical cells, and periligamentous and vasculonervous tissues of normal aspects. It did not show any pathological condition that could compromise the study of neural elements in the conditions proposed in the research.

For each ligament, a slide with anti-S100 immunohistochemistry (murine monoclonal antibody Clone 4C4.9 – ZETA Corporation) was prepared using the method as described by Kahn et al.[15] and by Mihalko et al.[16] following the processing and reaction according to the manufacturer's protocol.

The anti-S100 stained slide were analyzed by a Master of Prosthetics and Orthotics (M.P.O) and two doctors, professors of pathology, (R.J.V.M and L.T.M). An optical microscopy study was carried out with an increase of 100× (DI-115T microscope, DIGILAB Laboratory). Microscopic, and the visualization was performed throughout the entire tissue present in the slide. When anti-S100 stained neural tissue was identified in the field of vision of microscopy, the image was captured with a digital camera (model A59.4910, DIGILAB Laboratório) coupled to the microscope and the Micro Capture software (Ver6.9.12). The images were standardized in files with TIFF format. In each slide, the maximum number of images viewed was collected. All images were captured respecting the same standardization of magnification in microscopy, resolution and image size (Figure 1).[17]

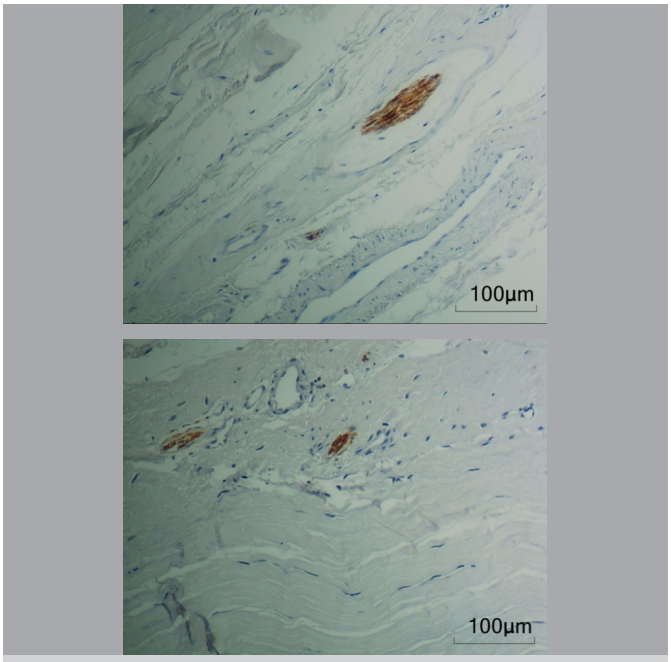

Figure 1. Histological sections of the PCL in case of the cadaver group (right) and OA (left). Staining with anti-S100 immunohistochemistry in which the presence of neural elements is evidenced in an increase of 100 times.

The images, standardized in size 1024 × 768 pixels with 96 dpi (dots per inch) RGB color, 1 layer, with a total of 786.432 pixels, were analyzed with the software GIMP 2.10.14 (GNOME Foundation). With this software, the "free hand" selection of the area corresponding to the neural tissue observed in the image was performed (Figure 2) and the pixels referring to the selected area (Figure 3)[17] were counted. The amount of pixels referring to neural tissues was recorded for each image as a percentage of the total pixels of the image.

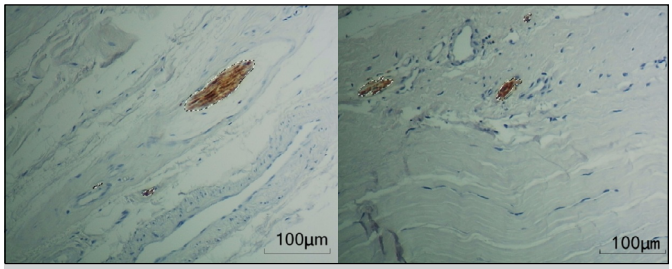

Figure 2. Selection of areas corresponding to neural elements in Figure 1.

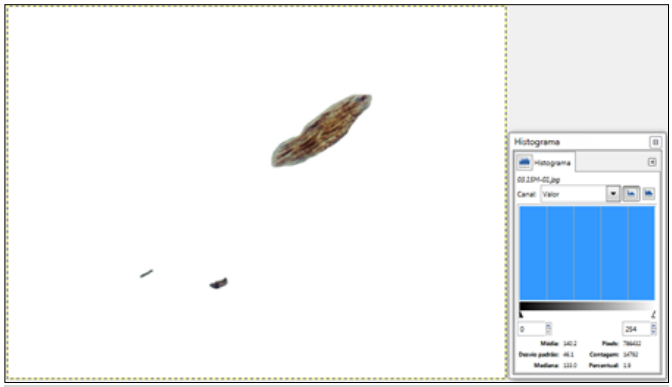

Figure 3. Quantification of neural elements through a histogram in channel value with subtraction of the value 255 of the white color of the background of the image, with pixel count corresponding to the neural elements as a percentage of the total pixels in Figure 2.

The data were tabulated and analyzed with the software Statistical Package for the Social Sciences (IBM-SPSS, version 24). A p-value of 0.05 was set for statistical significance.

RESULTS

Table 1 describes the distribution of individuals by gender and age. There was no statistically significant difference between the groups in relation to age (p = 0.256) and gender (p = 0.088) of the individuals.

Table 1. Sample distribution by age and gender

	Group		p-value
	Cadaver	Osteoarthritis	
Age			0.256
Average	59.8	71.1	
Standard Deviation	24.4	8,4	
95% CI	(49.5 – 70.1)	(62.2 – 75.9)	
Minimum	13	57	
Median	64.5	70.5	
Maximum	92	87	
Sex			0.088
Male	13	3	
Female	11	11	

Note: (*) p < 0.05 Kruskal-Wallis test

A total of 374 microscopy fields were recorded, 276 in the cadaver group and 98 in the OA group. The overall mean area of neural elements was 0.96% ± 0.67% for both groups together, and in the cadaver group it was 1.02% ± 0.67% and in the OA group it was 0.80% ± 0.64%, with ± statistically significant reduction in the OA group (p = 0.001) (Table 2 and Figure 4).

Table 2. Quantification of the area of neural elements (%) per profile under analysis.

	N	Average	Deviation Standard	95% CI		Minimum	Maximum	p-value
				LL	UL			
General	374	0.96	0.67	0.89	1.03	0.07	2.75	
Groups								0.001
Cadaver	276	1.02	0.67	0.94	1.10	0.09	2.75	
Osteoarthritis	98	0.80	0.64	0.67	0.93	0.07	2.46	
Groups (Over 60 years)								0.001
Cadaver	188	1.04	0.66	0.94	1.13	0.13	2.75	
Osteoarthritis	90	0.81	0.65	0.67	0.94	0.97	2.46	
Cadaver Group								0.766
Male	153	1.04	0.71	0.93	1.16	0.09	2.75	
Female	123	0.99	0.62	0.88	1.10	0.13	2.66	
Osteoarthrosis Group								0.003
Male	23	0.45	0.32	0.31	0.59	0.07	1.13	
Female	75	0.91	0.68	0.75	1.06	0.12	2.46	
Osteoarthrosis Group								0.847
Varus	84	0.81	0.66	0.66	0.94	0.07	2.46	
Valgus	14	0.77	0.55	0.45	1.08	0.21	1.82	

*Kruskal-Wallis test

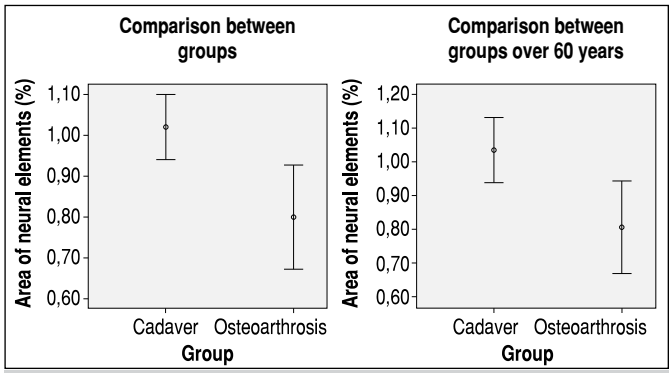

Figure 4. Means of neural element areas with 95% CI in relation to the group.

In order to minimize age bias in comparison, considering that the OA group is composed almost entirely of individuals over 60 years of age, groups including only individuals above this age group were compared. Nevertheless, the observation of a statistically significant reduction in the area of neural elements of the OA group was maintained (p = 0.001) (Table 2 and Figure 4).

There was no correlation between the age of the individuals studied and the area of the neural elements either in the cadaver group (p = 0.521) or in the OA group (p = 0.079) (Figure 5).

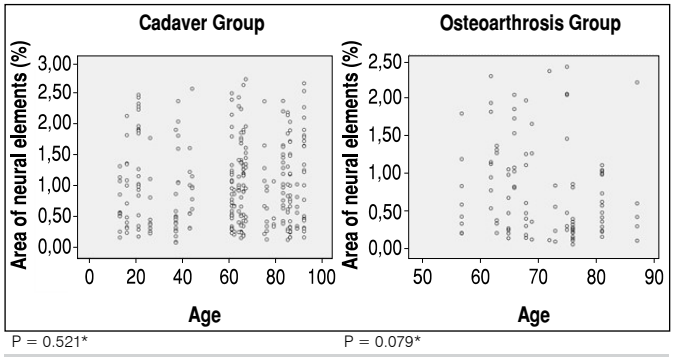

Figure 5. Scatter plots between age and quantification of the area of neural elements.

*: Pearson linear correlation.

In the cadaver group there was no statistically significant difference in the mean area of neural elements between the sexes (p = 0.766). In the OA group, there was a statistically significant reduction in males in relation to females (p = 0.003) (Table 2 and Figure 6).

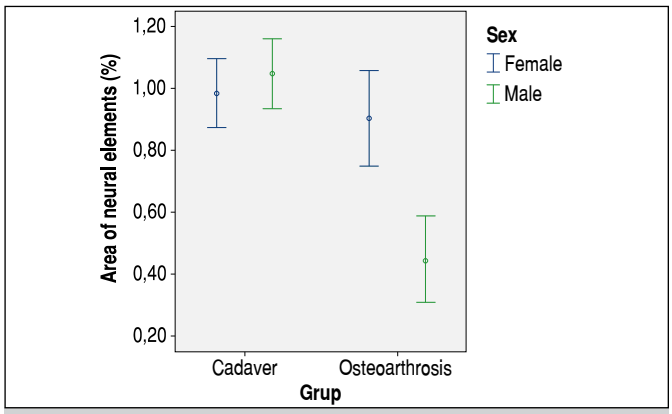

Figure 6. Means of neural element areas with 95% CI in relation to gender and group.

In the OA group there was no statistically significant difference in the area of neural elements between the knees with varus and valgus alignment (p = 0.847) (Table 2).

DISCUSSION

In the present study, the overall mean of the area occupied by neural elements per field of microscopy was 0.96% ± 0.67. In healthy knees, this mean was 1.02% ± 0.67%, comparable to the values of 0.958% ± 0.13% found in the healthy knees studied by Franchi, Zaccherotti and Aglietti[11] and at the value of 1% found by Schutte et al.[18] in the anterior cruciate ligament of healthy knees. On the knees with OA, in the present study we found an average of 0.83% ± 0.67%, being higher than the average found by Franchi, Zaccherotti and Aglietti[11] in their group of arthrosic knees, which was 0.44% ± 0.132%. Zhang and Mihalko[9] found quite different values of percentage of area occupied by neural elements in histological images studying two groups of knees with OA. In one group involving recovered TKA-CR PCLs, the average stained area in the cross-section studied by microscopy was 10.7% ± 5.1% in anti-S100 immunohistochemistry. In the second group, consisting of PCLs collected from TKA-PS, the average stained area was 11.1% ± 7% anti-S100. The authors did not observe a statistically significant difference in the area of the receptors between the groups. This large discrepancy in the areas in relation to the studies by Schutte et al.,[18] Franchi, Zaccherotti and Aglietti[11] and the present study may be due to different methodology in microscopic and/or histomorphometric study.

In the comparison between groups, Del Valle et al.[12] did not observe significant difference between the types of corpuscles, sizes and distribution between knees with OA and healthy. Franchi, Zaccherotti and Aglietti[11] observed a statistically significant reduction in the area occupied by the neural network and mechanoreceptors in the PCL of the knees with OA in relation to normal knees (p = 0.001), findings similar to those of Çabuk et al.,[2] that although they did not find a difference between knee groups with OA and normal with regard to the number of Pacini corpuscles, they observed that the number of Ruffini corpuscles, Golgi, free nerve endings and total nerve endings was significantly lower in the OA group (p < 0.05). Marczack et al.[3] observed in patients with primary OA a correlation between the severity of radiographic alterations and the presence of neural elements in PCL (p < 0.0001), so that samples with high degrees of degeneration had few receptors. They also observed a significant statistically decrease in the number of neural elements in patients with OA in relation to cadavers without joint disease (p < 0.0001). In the present study, a significant statistically reduction in the area of neural elements was observed in the OA group in relation to the cadaver group (p = 0.001), even with the comparison between groups with paired ages above 60 years (p = 0.001), reinforcing the role of OA in reducing the quantification of neural elements in PCL, since both groups were equated to the same age group.

The influence of age on the characteristics of neural elements in PCL has been verified in some studies. Moreno et al.,[7] who studied 15 PCLs of cadavers without joint morbidity, did not observe a correlation between the age of the cadaver and the total number of mechanoreceptors. A finding similar to that of Martins, Camanho and Rodrigues,[10] who identified immunomarkers for neural structures in 67.5% of the 34 PCLs of patients with primary OA, but did not observe a correlation between the age of the patients and the presence of neural elements. Colleoni et al.,[8] studying a male population of 19 cadavers without joint morbidity, did not observe a significant relationship between the total number of mechanoreceptors and age in the femoral or tibial portions of the PCL. However, in the tibial insertion, they observed a statistically

significant inverse correlation between age and the number of type I and type III mechanoreceptors, indicating that the older the age, the lower the number of these types of receptors in the tibial portion. In the present study, it was observed that there was no correlation between the mean area of neural elements and the age of the individuals evaluated both in the cadaver group and in the OA group. Thus, it is evident in the sample studied that the aging process was not related to a reduction in the quantification of neural elements in PCL.

Moreno et al.[7] and Colleoni et al.[8] point out that they did not find data in the literature demonstrating or suggesting the need for a comparative study in relation to gender, thus, they included only male individuals in an attempt to standardize their samples. In their work, Martins, Camanho and Rodrigues[10] observed that there was no association between sex and the presence of neural elements. In the present study, it was observed that in the knees of the cadaver group there was no difference in the quantification of the area of neural elements between the sexes ($p = 0.766$). However, in the OA group, there was a lower quantification of the area of neural elements in males than in females ($p = 0.003$). It is evident, that although the literature does not pay attention to the difference in the quantification of neural elements in knee PCL between the sexes, this variable is necessary in order to better understand the characteristics of neural structures in knee PCL. This need reinforces the discussion about the differences between the sexes not only in some aspects of proprioception, but also in studies evaluating the knee joint.[19,20]

Evaluating the neural elements and their behavior in relation to knee alignment in varus or valgus, Martins, Camanho and Rodrigues[10] observed that neural structures were more frequent in varus knees (77%) than in the valgus (50%), statistically significant difference ($p = 0.048$). In opposition, in the present study, no statistically significant difference was observed in the quantification of neural elements between the varus and valgus knees ($p = 0.847$). No other study was identified that evaluated limb alignment and neural elements in PCL.

There is no data in the literature to suggest any observation about the laterality or dominance of the limb in the study of neural elements. This study also did not analyze these variables, although it does not rule out the relevance of studying the subject, particularly in view of the interest in the discussion about the laterality or dominance of the limb and its relationship with proprioception.[19,20]

Limitations for the study are the number of slides prepared for each ligament. Although it is believed that a greater number of histological sections could provide better representativeness of the neural elements in the analyzed ligaments, the standardization of histological and histomorphometric methodology partially circumvent this problem. Another technical limitation is the non-standardization of histological sections in relation to ligament regions, i.e., femoral, tibial and medium substance bone insertions. The systematized study with search for neural elements along the entire histological slide minimizes this limitation, since all the cutting tissue could be examined.

Knowing the characteristics of neural elements in PCL, particularly under different sexes, ages, morbidity conditions, laterality and dominance may support therapeutic decisions, such as the indication of resection or not of the posterior cruciate ligament when performing a TKA, assisting in the identification of specific groups that may be better conducted under one form or another of treatment. In another case, the knowledge of specific groups with greater vulnerability from the proprioceptive perspective may help in the planning, development and indication of preventive measures against acute or chronic joint injuries.

CONCLUSION

A reduction was demonstrated in the quantification of neural elements in PCL of individuals affected by OA, compared to non-arthritic individuals, and this quantification is not related to age or the mechanical axis of the lower limb.

AUTHORS' CONTRIBUTION: Each author contributed individually and significantly to the development of this article. MPO: conception and writing of the article, acquisition, analysis and interpretation of the data; RJVM: analysis and interpretation of histological studies; LTM: analysis and interpretation of histological studies; STP: execution of histology papers; DAL: critical review of the article; JADL: critical review and intellectual concept of the article.

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ANALYSIS OF STERNAL CURVATURE PATTERNS IN PATIENTS WITH PECTUS AND CONTROL

ANÁLISE DOS PADRÕES DE CURVATURA ESTERNAL EM PACIENTES COM PECTUS E CONTROLES

Davi de Podestá Haje[1,2], Kelsen de Oliveira Teixeira[2], Moacir Silva Neto[2], José Batista Volpon[3], Paulo Sergio Mendlovitz[4], Paulo Dolabela[5]

1. Centro Clínico Orthopectus, Brasília, DF, Brazil.
2. Department of Pediatric Orthopaedics and Physical Medicine and Rehabilitation, Hospital de Base do Distrito Federal, Secretaria de Estado da Saúde do Distrito Federal, Brasília, DF, Brazil.
3. Department of Biomechanics, Medicine and Rehabilitation of the Locomotor System, University of São Paulo, Ribeirão Preto, SP, Brazil.
4. Sabin Medicina Diagnóstica, Brasília, DF, Brazil.
5. Department of Radiology and Medical Imaging, Clínica Villas Boas, Brasília, DF, Brazil.

ABSTRACT

Objective: To analyze reformatted sagittal sternal tomography images and classify sternal body curvature types, and compare different types of *pectus* populations with one another and with normal individuals. Methods: In total, 50 controls and 167 pectus patients were selected for chest CT to analyze the median sagittal plane, of whom 89 had *pectus carinatum (*mean age, 12 ± 10 years) and 78 *pectus excavatum* (mean age, 14 ± 10 years). Clinical types of *pectus* were classified as inferior, superior, or lateral *pectus carinatum,* and localized or broad *pectus excavatum.* The following types of sternal patterns were defined: gradual vertical curve, gradual posterior curve, gradual anterior curve, proximal third curve, middle third curve, distal third curve, anterior rectilinear, vertical rectilinear, and posterior rectilinear. Statistical analyses were performed to compare the different types of *pectus* with one another and with the control group. Results: Patients with different thoracic deformities, but with similar sternal curvature patterns, were observed. Some types of sternal curvature were significantly more frequent in certain types of *pectus* ($p < 0,05$). The gradual vertical curve and anterior rectilinear types prevailed in controls ($p < 0,05$). Conclusion: Some sternal curvature patterns were more frequent than the others in certain types of *pectus* and the controls. ***Level of Evidence II, Prognostic studies – investigating the effect of a patient characteristic on the outcome of disease.***

Keywords: Pectus Carinatum. Pectus Excavatum. Thorax. Tomography. Tomography, X-ray Computed.

RESUMO

Objetivo: Avaliar a reformatação sagital tomográfica do esterno por meio da análise de uma classificação do tipo de curvatura do corpo esternal nos diferentes tipos de pectus, comparando-os entre si e com indivíduos normais. Métodos: 50 controles e 167 pacientes submetidos à TC do tórax para análise da reconstrução sagital no plano mediano, sendo 89 com pectus carinatum (idade média, 12 ± 10 anos) e 78 com pectus excavatum (idade média, 14 ± 10 years). Os tipos clínicos de pectus foram classificados em: pectus carinatum superior, inferior e lateral, e pectus excavatum amplo ou localizado. Foram definidos os seguintes tipos de padrões esternais: curvo gradativo vertical; curvo gradativo posterior; curvo gradativo anterior; curvo terço proximal; curvo terço médio; curvo terço distal; retilíneo anterior; retilíneo vertical; e retilíneo posterior. Foi realizada análise estatística entre o grupo pectus e controle, e entre diferentes tipos de pectus. Resultados: Observamos pacientes com deformidades torácicas diferentes, mas com esternos com padrão de curvatura semelhante. Alguns tipos de curvatura esternal são significativamente mais frequentes em alguns tipos de pectus ($p < 0,05$). Em controles prevaleceram os tipos curvo gradativo vertical e retilíneo anterior ($p < 0,05$). Conclusão: Alguns tipos de curvatura esternal são mais frequentes que outras em determinados tipos de pectus e controles. ***Nível de Evidência II, Estudos prognósticos – investigação do efeito de característica de um paciente sobre o desfecho da doença.***

Descritores: *Pectus Carinatum. Pectus Excavatum. Tórax. Tomografia. Tomografia Computadorizada.*

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INTRODUCTION

The anterior thoracic wall has been well studied in images acquired in the coronal and axial planes.[1,2] However, few authors have analyzed the sagittal plane region in cases of anterior chest deformity or *pectus*; thus, differentiating the types of *pectus* and distinguishing these patients from normal individuals may be useful.

Haje et al.[3] developed radiographic indices that show the relative length of various sternal segments visualized in the profile incidence.

All authors declare no potential conflict of interest related to this article.

The study was conducted at Centro Clínico Orthopectus.
Correspondence: Davi P. Haje. SMHN, Q. 2 Bl. A, sala 804, Edifício de Clínicas, Asa Norte, Brasília, DF, Brazil, 70710904. davihaje@yahoo.com.br

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From this analysis, the authors concluded that the developmental changes in the sternum, such as ossification and maturation with consequent shortening and curving of the body, seem to have a major influence on the etiology of superior *pectus carinatum* and a minor influence on other types of *pectus*.[3]
Through the evaluation of coronal images, some sternal anatomical variations have been described, especially those related to skeletal maturation and age.[4]
Interpreting tomographic sections in sagittal reformatted images of patients with *pectus* can be difficult. The sternal body curvature patterns in the sagittal plane may pose challenges when distinguishing patients with *pectus* from normal individuals. Therefore, a better knowledge of the sternal anatomy in different types of *pectus* in the sagittal plane is a necessary propaedeutic for radiologists, orthopedists, and thoracic surgeons, which may help them to better understand the etiopathogenesis of these deformities and improve treatment.
Our study aimed to evaluate the reformatted sagittal sternal computed tomography (CT) images, analyze and classify sternal body curvature types in the sagittal plane in normal and *pectus* populations, and verify any predefined patterns that may exist.

MATERIALS AND METHODS

Institutional Review Board approval (42165414.5.0000.5553) was obtained. This was a retrospective analysis of medical records from 5,750 individuals with *pectus* treated between February 2004 and September 2014 at our Hospital.

Study participants

We selected 181 consecutive patients with *pectus* from this population that had undergone CT of the thorax involving the sternum and costal cartilages (1 mm slice thickness and interval). The exclusion criteria were previous resection surgery of the costal cartilage (n = 3), iatrogenic *pectus* (n = 1), and deformities associated with scoliosis greater than 10° (n = 10). Finally, 67 patients with *pectus* and 50 control individuals were included for analyzing the sternum in the sagittal plane. The patients with *pectus* and the controls were subdivided for the analysis, as shown in Table 1.

Table 1. Subdivisions of the *pectus* and control groups.

Pectus group (n = 167, 133 men)					Control group
pectus carinatum (n = 89, mean age, 12 10 years)			*pectus excavatum* (n = 78, mean age, 14 10 years)		(n = 50, mean age, 29 23 years)
IPC (n = 52)	LPC (n = 24)	SPC (n = 13)	LPE (n = 52)	BPE (n = 26)	control (n = 50)

IPC: inferior *pectus carinatum*; LPC: lateral *pectus carinatum;* SPC: superior *pectus carinatum;* LPE: localized *pectus excavatum*; BPE: broad *pectus excavatum*.

Clinical diagnosis was established by the evaluators (DPH, MSN), who classified *pectus* according to the predominant type as follows: inferior *pectus carinatum* (IPC) (Group I), lateral *pectus carinatum* (LPC) (Group II), superior *pectus carinatum* (SPC) (Group III), localized *pectus excavatum* (LPE) (Group IV), and broad *pectus excavatum* (BPE) (Group V).[5]
Patients in the control group underwent chest CT scans (1 mm slice thickness and interval) for other reasons. They did not have *pectus* or spinal deformities, and did not report prior surgeries in the sternal region. The controls were randomly selected from the image banks of the radiology clinics involved in the study.

Analysis

The images were selected in Digital Imaging and Communications in Medicine (DICOM®) format using the OsiriX v. 5.8.2 32-Bit software (Pixmeo SARL, Bernex, Switzerland) for the image reconstruction. Images in the sagittal plane were standardized using the MIP 3D evaluation software to amplify the slices since the sternum of these patients may present substantial variations in the coronal and sagittal planes. The closest possible slice to the median plane of the sternum was analyzed.
The following types of sternal patterns were defined by the main author based on the analysis of sternal body images (Figures 1 and 2):

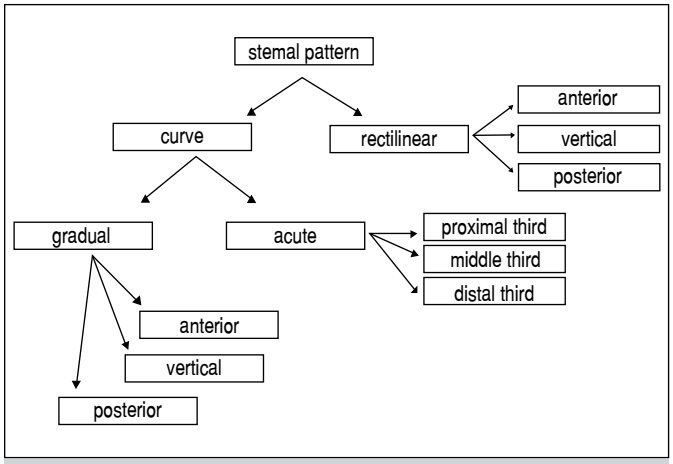

Figure 1. Flowchart showing the sternal curvature patterns.

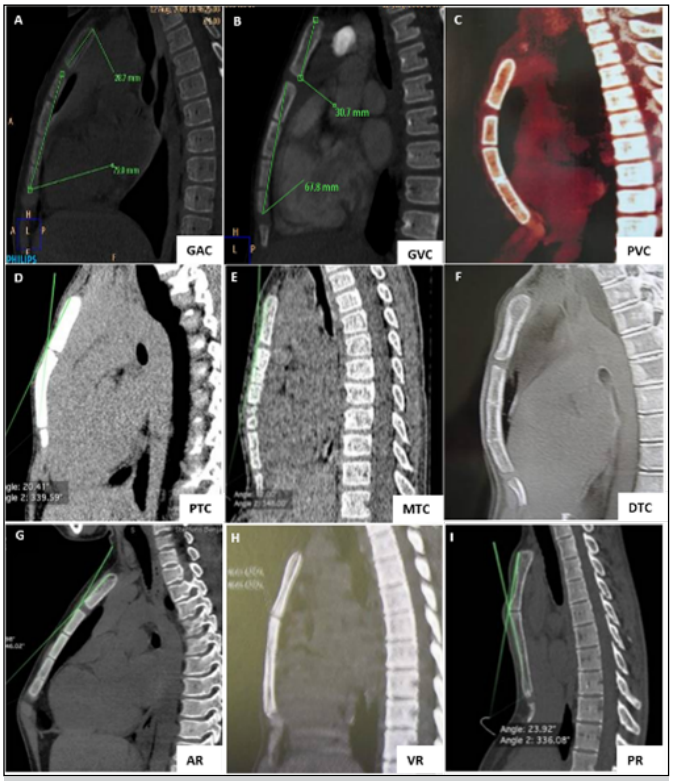

Figure 2. Illustration of sternal patterns. Sternum: gradual anterior curve (GAC); gradual vertical curve (GVC); gradual posterior curved (GPC); proximal third curve (PTC); middle third curve (MTC); distal third curve (DTC); anterior rectilinear (AR); vertical rectilinear (VR); and posterior rectilinear (PR).

- Gradual anterior curve: the sternum has a gradual curve throughout its body, with its lower end in an anterior direction;
- Gradual vertical curve: the sternum has a gradual curve throughout its body, with its lower end in a vertical direction;
- Gradual posterior curve: the sternum is gradually curved throughout its body, with its lower end in a posterior direction;
- Proximal third curve: the sternum has an acute angulation in its proximal third only;
- Middle third curve: the sternum has an acute angulation in its middle third only;
- Distal third curve: the sternum has an acute angulation in its distal third only;
- Anterior rectilinear: the sternum is all rectilinear with its distal end in an anterior direction;
- Vertical rectilinear: the sternum is all rectilinear with its distal end in a vertical direction;
- Posterior rectilinear: the sternum is all rectilinear with its distal end in a posterior direction.

Statistical analysis

The SPSS software package version 15.0 (IBM Corp., Armonk, NY) was used for the statistical analysis and the comparisons of 1) each *pectus* type and the control group and 2) between each type of *pectus*. The Pearson's chi-squared test (cross-tabulation) was used to compare tomographic parameters among all groups. One-way analysis of variance (ANOVA) for independent groups was used to calculate the difference of means of radiographic parameters among the groups. A p-value less than or equal to 0.05 was considered statistically significant.

RESULTS

Table 2 shows the sternal body curvature patterns found in the control group and patients with different types of *pectus*.

Table 2. Types of sternum body curvatures in the control and *pectus* groups.

	CONTROL GROUP	SPC	IPC	LPC	LPE	BPE
Anterior rectilinear	13 (26%)	0 (0%)	26 (50%)	7 (29.1%)	4 (7.7%)	5 (19.2%)
Gradual vertical curve	24 (48%)	4 (30.7%)	11 (21.1%)	7 (29.1%)	8 (15.4%)	0 (0%)
Gradual anterior curve	4 (8%)	0 (0%)	9 (17.3%)	4 (16.7%)	1 (1.9%)	0 (0%)
Vertical rectilinear	3 (6%)	1 (7.6%)	0 (0%)	0	0 (0%)	3 (11.5%)
Distal third curve	4(8%)	2 (15.3%)	2 (3.8%)	3 (12.5%)	4 (7.7%)	4 (15.3%)
Gradual posterior curve	0 (0%)	1 (7.6%)	2 (3.8%)	3 (12.5%)	32 (61.5%)	10 (38.4%)
Proximal third curve	1 (2%)	4 (30.7%)	2 (3.8%)	0	2 (3.8%)	1 (3.8%)
Middle third curve	1 (2%)	1 (7.6%)	0 (0%)	0	1 (1.9%)	0 (0%)
Posterior rectilinear	0 (0%)	0 (0%)	0 (0%)	0	0 (0%)	3 (11.5%)
TOTAL	50	13	52	24	52	26

IPC: inferior pectus carinatum; LPC: lateral pectus carinatum; SPC: superior pectus carinatum; LPE: localized pectus excavatum; BPE: broad pectus excavatum.

There was a high incidence of gradual vertical and anterior rectilinear curvature in the control group (p = .001) (Figure 3).

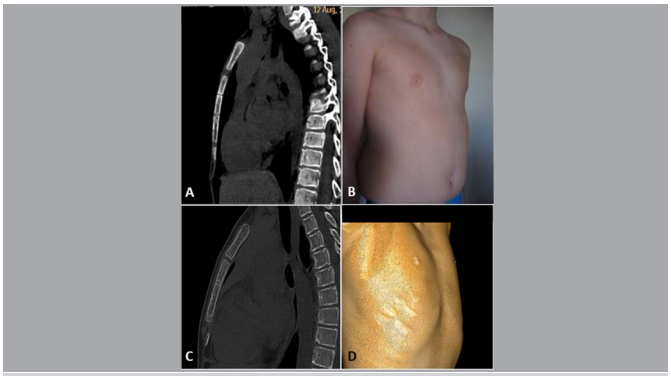

Figure 3. Examples of the most common sternal patterns in the control group: the vertical curved (A and B) and the anterior rectilinear types (C and D).

Comparison between the control and *pectus* groups

The following statistically significant findings were found when comparing sternal patterns between each *pectus* type and the controls (n = 50):
a) *SPC versus controls:* Higher prevalence of proximal third and gradual posterior curves and a lower prevalence of anterior rectilinear in patients with SPC (n = 13) than in the controls (n = 50) (p = .03);
b) *IPC versus controls:* Higher prevalence of the anterior rectilinear type and a lower prevalence of the gradual vertical curve and vertical rectilinear types in IPC (n = 52) than the controls (p = .01);
c) *LPE versus controls:* Patients with LPE (n = 52) had a lower prevalence of anterior rectilinear, gradual vertical, and vertical rectilinear types and higher prevalence of gradual posterior curve than the controls (p = .00);
d) *BPE versus controls:* Patients with BPE (n = 26) presented a higher prevalence of gradual posterior and posterior rectilinear types and a lower prevalence of gradual vertical curve than the controls (p = .00); and
e) There was no significant difference between the control group and patients with LPC (n = 24) (p > .05).
We clinically observed patients with the same type of *pectus* but with different sternal tomographic patterns (Figures 4 to 7).

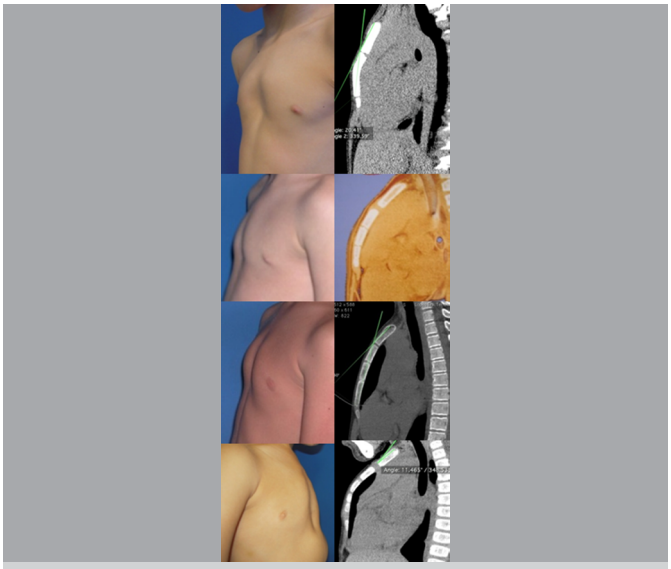

Figure 4. Patients with the same clinical type of *pectus* (SPC), but with different sternal patterns. Even the clinical types that were classified as SPC, representing cases in which the chest was more prominent than normal in its most proximal region, were not necessarily the same.

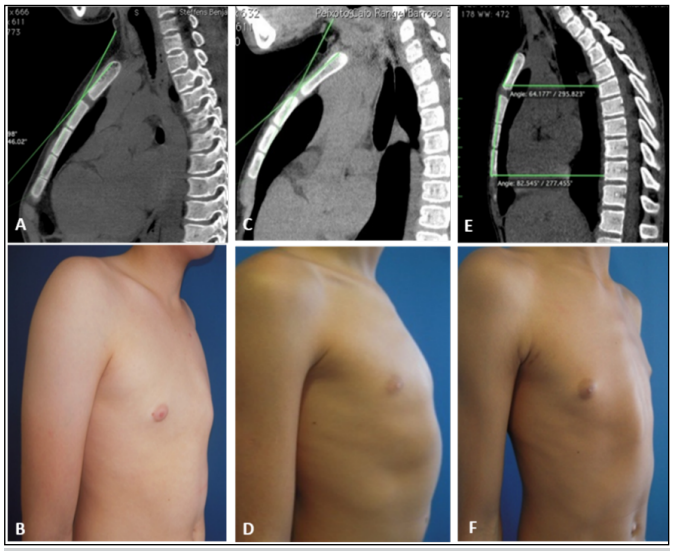

Figure 5. Patients with the same clinical type of *pectus* (IPC), but different sternal patterns. Although it was clear that the clinical type was IPC, we observed that the sternal patterns, anterior rectilinear, and gradual anterior curvature had the clinical apex of the deformity closer to the mammary line. In the gradual vertical curvature, this clinical apex seemed more distal and the whole sternal body seemed projected more anteriorly and not only its distal portion.

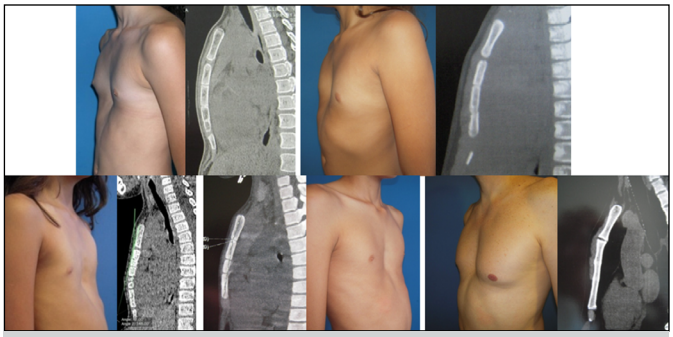

Figure 6. Patients with the same clinical type of *pectus* (LPE), but different sternal patterns. Note that even the clinical types classified as LPE, representing cases in which the thorax presented a localized and central depression area, were not necessarily the same.

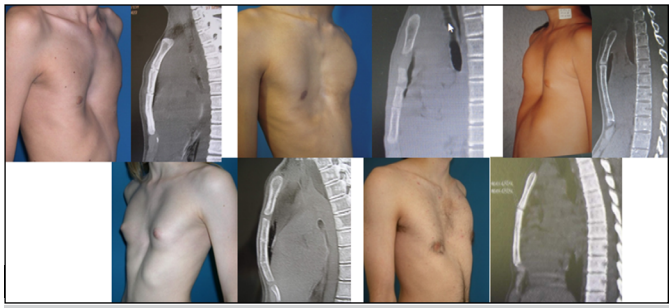

Figure 7. Patients with the same clinical type of *pectus* (BPE), but different sternal patterns. Note that even the clinical types classified as BPE, representing cases in which the chest presents a wide area of depression, were not necessarily the same.

Analysis between different types of pectus

The following statistically significant findings were found when comparing sternal patterns between each type of *pectus*:

a) *BPE versus LPE:* Patients with LPE had a higher prevalence of gradual vertical and posterior curve and a lower incidence of vertical and posterior rectilinear than the patients with BPE ($p = .003$);
b) *L = IPC versus LPE:* Patients with LPC had a higher prevalence of anterior rectilinear and gradual anterior curve and lower prevalence of gradual posterior curved than the patients with LPE ($p = .00$);
c) *SPC versus LPE:* Patients with SPC had a higher prevalence of vertical rectilinear and proximal third and middle third curves, and lower prevalence of gradual posterior curve than the patients with LPE ($p = .00$);
d) *SPC versus BPE:* Patients with SPC had a higher prevalence of gradual vertical curve and proximal third curve, and lower prevalence of gradual posterior curve than the patients with BPE ($p = .00$);
e) *SPC versus IPC:* Patients with SPC had a higher prevalence of vertical rectilinear and distal and proximal third curve types, and lower prevalence of anterior rectilinear and gradual anterior curve than the patients with IPC ($p = .00$);
f) *SPC versus LPC:* Patients with SPC had a higher prevalence of proximal third curve types and a lower incidence of anterior rectilinear and gradual anterior curve than the patients with LPC ($p = .016$);
g) *LPC versus LPE:* Patients with LPC ($n = 24$) had a higher prevalence of anterior rectilinear and gradual anterior curve, and lower prevalence of gradual posterior curve than the patients with LPE ($n = 52$) ($p = .00$); and
h) There was no significant difference between the IPC and LPC groups of *pectus* regarding the type of sternal curvature ($p = .24$) ($p > .05$). We observed patients with different clinical types of *pectus* but with very similar sternal patterns (Figure 8).

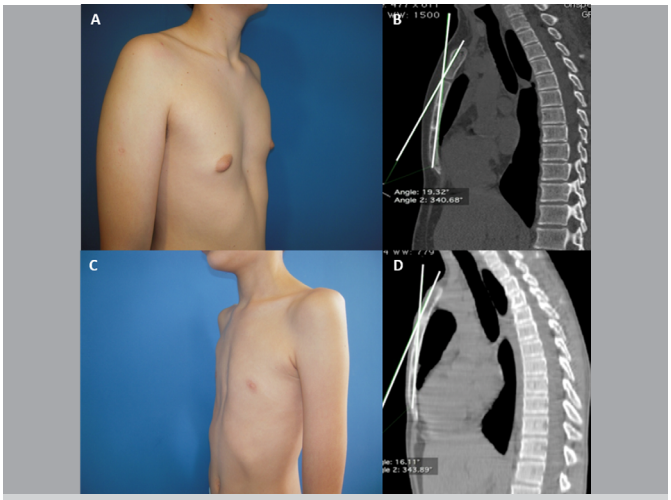

Figure 8. Patients with localized *pectus excavatum* (a) with gradual vertical curve sternal pattern (b) and another patient with lateral *pectus carinatum* (c) with the same sternal pattern (d).

DISCUSSION

This study created radiographic parameters that can eventually be described in reports on the thoracic region, as they help clarify the shape of the sternal bone in the sagittal plane in normal individuals and patients with *pectus*.
In the control group, the gradual posterior curve and posterior rectilinear types were not found, whereas the gradual vertical curve and anterior rectilinear types prevailed, which is an interesting and novel observation. A radiologist that did not previously clinically analyzed the patient, but analyzed an exam that has sternum of the gradual posterior curve and posterior rectilinear types, will know that the patient probably has pectus. It is not uncommon for radiologic exams of *pectus* patients with the description of "normal" or "no alterations".

We also observed patients with different *pectus* deformities but with similar curvature patterns of the sternum in sagittal reconstruction, which is also novel. There were patients with the same type of *pectus* but with different types of sternal body curvatures. That is an important observation when analyzing the *pectus* etiopathogeneses. In some cases, growth abnormalities in the sternum region or sternum pattern curvature may not be related to *pectus* etiology or appearance, since some different clinical *pectus* have the same radiologic sternum pattern.

Except for the posterior rectilinear type that occurred only in BPE cases, the other types of sternal curvatures were not specific to patients with *pectus*. Some types were more frequent, whereas others were not found in certain *pectus*. In the cases of *pectus excavatum*, the gradual posterior curve sternum was more frequent than other types. Most patients in the IPC, and LPC group showed anterior rectilinear and gradual vertical curves. In the SPC group, the proximal third curve and gradual vertical curve together accounted for 61.4% (8 of 13 patients) of the cases, the former being rare.

Some consider the sternum as the key factor causing *pectus*, with its distal end being more depressed in cases of *pectus excavatum*, and the opposite in cases of *pectus carinatum*.[6] However, our study showed that this does not always occur and that there are cases of anterior rectilinear, vertical rectilinear, gradual anterior curve, and gradual vertical curve types in *pectus excavatum* cases. We also observed cases of *pectus carinatum* with the distal end of the sternum inclined in the posterior direction.

The clinical types classified as SPC, LPE, and BPE were not necessarily the same, suggesting the need to improve the clinical classification of these *pectus* subtypes. Haje et al.[5] recently subdivided the LPE and SPC classifications. Better defined clinical subtypes may help create or improve tomographic parameters to differentiate them.

Due to variation in the shape of the anterior thoracic wall in normal individuals, it may be difficult to clinically and radiologically define the limits between a mild case of *pectus* and a patient with a normally shaped anterior thoracic wall. Our extensive experience in treating these deformities with orthoses and exercises shows that there are patients with discrete *pectus* that wish to undergo treatment and patients with mild or moderate *pectus* that have always considered themselves as normal and have no intention of undergoing therapy. When Haller's index was previously evaluated, it was measured at the point of greatest sternal depression in the sternal region, being evaluated before and after *pectus excavatum* correction surgery.[2] The present radiological parameters may also be used in the pre- and post-treatment evaluation of patients with *pectus excavatum*, especially in corrective surgeries with sternal body osteotomies, such as the surgical treatment of superior or Currarino *pectus* types (SPC).[7] The knowledge of several sternal patterns in the sagittal analysis of the sternal region may help to better understand the etiopathogenesis of *pectus* deformities and plan the most adequate treatment in surgical cases and suggest appropriate classification criteria.

Before the analysis, it was important to find the midline of the sternum, which is not necessarily the midline of the body. We also know that may be inclined or obliquus to the body when the sternum is seen in the coronal plane, thus complicating tracing the median line.

A present bias was that the analyzed parameters were subjected to intra- and inter-examiner interpretation variations. Further studies are necessary to verify the reliability of our method. Although we used a control group, it is unknown that tomographic parameters vary with age and sex in normal/control individuals.

Initially, in some situations, a CT scan of the anterior thoracic wall was requested by the authors to better understand these deformities. Recently, CT scans are no longer requested because tomographic and clinical patterns seemed to repeat themselves and this examination is not a determining factor for orthosis and exercise-based therapy;[5,8] moreover, there are growing concerns regarding radiation by the examination.[5] The examination can sometimes be used to evaluate prognosis in selected patients, especially in mild SPC in children to evaluate early fusion of the manubriosternal region or sternal shortening, and in some LPC cases in which the pectoral region is asymmetrical, and the degree of bone and soft tissue deformity (breast and/or muscle involvement). Most of the cases in our study were detected before 2009. The cases after that year included CT examinations requested by other colleagues before referral to our *pectus* treatment center.

CONCLUSION

In conclusion, the suggested classification of sternal curvature types provided initial radiological parameters in patients with *pectus* and controls and evidence of differentiation between them.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article. DPH: conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revising it critically for important intellectual content, final approval of the version to be published; KOT: conception and design of the study, acquisition of data, analysis and interpretation of data and final approval of the version to be published; MSN: conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revising it critically for important intellectual content, final approval of the version to be published; JBV: conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revising it critically for important intellectual content, final approval of the version to be published; PSM: conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revising it critically for important intellectual content, final approval of the version to be published; PD: drafting the article, revising it critically for important intellectual content, final approval of the version to be published.

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COMPARISON OF TWO METHODS OF FIXATION OF SUPRACONDYLAR FRACTURES OF THE HUMERUS IN CHILDREN

COMPARAÇÃO DE DOIS MÉTODOS DE FIXAÇÃO DE FRATURAS SUPRACONDILIANAS DO ÚMERO EM CRIANÇAS

HENRIQUE MELO NATALIN[1], *JÉSSICA COLAMARINO SESSA DA SILVA*[2], *JOSÉ BATISTA VOLPON*[1]

1. Universidade de São Paulo, Ribeirão Preto Medical School Teaching Hospital, Ribeirão Preto, SP, Brazil.
2. Universidade de São Paulo, Ribeirão Preto Medical School, Ribeirão Preto, SP, Brazil.

ABSTRACT

Objective: To compare the outcomes of the fixation of complete and displaced supracondylar humeral fractures in children with two different Kirschner wire configurations. Methods: The type of fixation was randomized to either crossed (19 cases), or two divergent lateral Kirschner wires (24 cases). The comparison was made six months later between the two treated groups and each group with the non-fractured elbow (clinical alignment, range of motion, Baumann angle, and lateral humeral capitellar angle). Results: 43 children were evaluated (65% boys) with a mean age of six years and five months. The carrying angle (p = 0.94), extension (p = 0.89), and the Flynn´s criteria (p = 0.56) were similar between the groups. The flexion was slightly smaller for the crossed wire group (p = 0.04), but similar to the uninjured side. The Baumann angle was not different between the two fixations (p = 0.79) and the contralateral side (p = 0.1). The lateral humeral capitellar angle was slightly greater for the lateral pinning (p = 0.08), but with no difference with the uninjured elbow (p = 0.62). No iatrogenic injuries were observed. Conclusion: Both fixations presented similar outcomes that did not significantly affect the carrying angle in relation to the non-fractured side. ***Level of evidence II, Therapeutic study – Investigating the results of treatment.***

Keywords: Humeral Fractures. Bone Wires. Children.

RESUMO

Objetivo: Comparar os resultados da fixação das fraturas supracondilianas completas e desviadas do úmero de crianças com dois tipos de configuração de fios de Kirschner. Método: O tipo de fixação foi aleatorizado para fixação com dois fios de Kirchner cruzados ou laterais divergentes. Depois de seis meses foi feita a comparação entre os dois grupos fixados entre si e cada um deles com o lado não fraturado do mesmo paciente (alinhamento clínico, arco de movimento, critérios de Flynn, ângulos de Baumann e capituloumeral). Resultados: Participaram do estudo 43 crianças (65% meninos), com idade média de seis anos e cinco meses. A extensão (p = 0,89), o ângulo de carregamento (p = 0,94) e os critérios de Flynn (p = 0,56) foram semelhantes entre os dois grupos, sem ocorrência de lesões iatrogênicas. A flexão foi discretamente menor no grupo com fios cruzados (p = 0,04), mas próximo do cotovelo normal. O ângulo de Baumann não apresentou diferença entre as duas fixações (p = 0,79), bem como com o lado não fraturado (p = 0,01). O ângulo capituloumeral foi ligeiramente maior (p = 0,08) nos fios laterais, mas sem diferença em relação lado normal (p = 0,62). Conclusão: As duas fixações apresentaram resultados similares e não alteraram significativamente o ângulo frontal do cotovelo em relação ao lado não fraturado. ***Nível de evidência II, Estudo terapêutico – Investigação dos resultados do tratamento.***

Descritores: *Fraturas do Úmero. Fios Ortopédicos. Crianças.*

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INTRODUCTION

Supracondylar humeral fractures, the most common in the immature elbow,[1] when displaced, should be reduced and fixed by means of the percutaneous technique with two or three Kirschner wires, as they present intrinsic instability. The wires can be inserted in crossed configuration, one into each epicondyle, or all of them (two or three) through the lateral epicondyle. When crossed, fixation is mechanically more stable, but there is a higher risk of injury to the ulnar nerve.[2]

Among North American orthopedists, 30% prefer crossed wires, 33% prefer insertion of two lateral wires, and 37% prefer the use of three lateral wires.[3] Therefore, the options are quite balanced and wire configuration seems to be a surgeon's personal choice.

The Gartland classification[1] has been reviewed and includes the types in flexion and those in extension I, II, III or IV,[4] depending on the degree of affection of the fracture and characteristic of the displacement. There are several publications on treatment types, but most of them refer to retrospective series. A meta-analysis recommends lateral wires

All authors declare no potential conflict of interest related to this article.

The study was conducted at the Department of Orthopedics and Anesthesiology of the Ribeirão Preto Medical School Teaching Hospital, University of São Paulo.
Correspondence: Henrique Melo Natalin. Rua Carlos de Campos, 1361, apartamento 2, Monte Alegre, Ribeirão Preto, São Paulo, Brazil. 14051080. henrique.melo.6@hotmail.com

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for type II fractures and crossed wires for types III or IV fractures, with mini access technique for medial wire,[5] while another recommends the use of laterally inserted wires.[6] Finally, a third concluded that there is not enough evidence to recommend one or another configuration, but that, if the surgeon wants to avoid the potential risks of iatrogenic injury to the ulnar nerve, the lateral insertion of wires is safer.[7]

Based on these assumptions, we conducted a random and prospective study whose objective was to analyze the outcomes of the treatment of displaced supracondylar humeral fracture and fixed with two Kirschner wires inserted crosswise (through the lateral and medial condyles) or only through the lateral condyle.

MATERIALS AND METHODS

The project was approved by the Institution's Ethics Committee (CAAE): 02703418.8.0000.5440). The individuals included were treated at an emergency unit of the Unified Health System between June 2015 and December 2018. The inclusions were: complete and displaced supracondylar humeral fractures (Gartland type III [1]) (Figure 1) in children of any age. The legal guardians authorized the inclusion in the study and committed to adhere to the postoperative follow-up for at least six months. Exclusion criteria were other associated fractures, head trauma, Gartland I and II fractures,[1] bilateral, exposed fractures, need for open reduction, presence of previous trauma sequelae on any of the elbows, fixation with more than two metallic wires in the same epicondyle, and loss of follow-up.

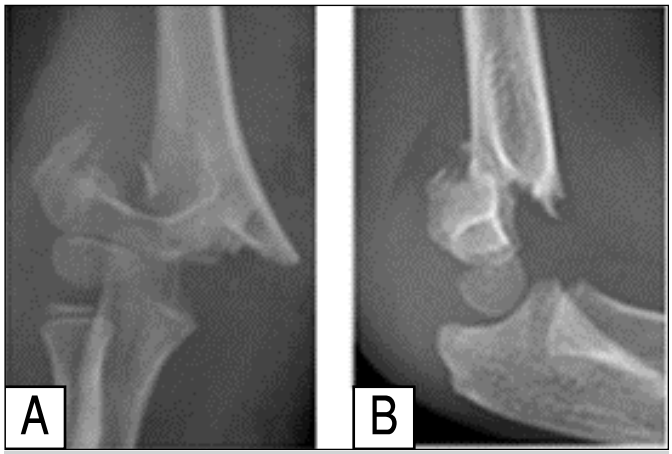

Figure 1. Illustration of a typical fracture classified as Gartland type III. The fracture is complete, displaced in more than one plane and unstable.

Initial care involved careful evaluation of limb circulatory conditions and possible neurological injuries. The randomization of the type of fixation (crossed or just lateral wires) was performed through the website *random.org* (https://www.random.org/).

According to the flow chart in Figure 2, there were 734 cases of orthopedic pediatric trauma during the study period, with 107 supracondylar fractures (14.5%). Of these, 61 were completely displaced and classified as Gartland III (1) (57%) and randomized for treatment with two crossed Kirschner wires, or two divergent lateral wires. There was exclusion of two patients that underwent open reduction and three who did not attend follow-up for a minimum of six months. The final sample consisted of 43 cases, of which 24 cases with fixation with lateral wires (56%) and 19 cases with fixation with crossed wires (44%).

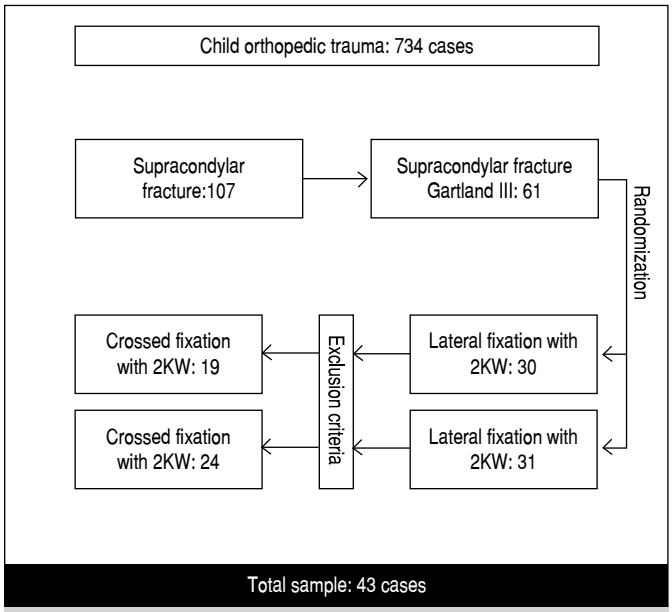

Figure 2. Patient selection flow chart. KW: Kirschner wire; Gartland III: complete and displaced fractures.

Fracture reduction and fixation technique

Fracture reduction was performed under general anesthesia, with the child in the supine position and the fractured upper limb resting on an auxiliary table for the hand. After routine antisepsis procedures, the following steps were performed under the control of the image intensifier: traction with the elbow in semiflexion, correction of the lateral or medial displacement, and correction of the posterior displacement with support on the olecranon, associated with elbow flexion. After confirmation of the adequacy of the reduction (displacements corrected and alignment of the medial and lateral elbow columns). In cases with only lateral fixation, flexion was maintained, the lateral epicondyle was identified, and two 2.0 mm thick Kirschner wires directed towards the lateral elbow column were introduced in a divergent manner until they reached the opposite cortex (Figure 3A). For the crossed wires, the wire through the lateral epicondyle was inserted first, as already described. Then, the elbow was partially extended, the epicondyle was palpated, and a small surgical access was made to identify the ulnar nerve. Then, the Kirschner wire was introduced towards the medial column, until reaching the opposite cortex (Figure 3B).

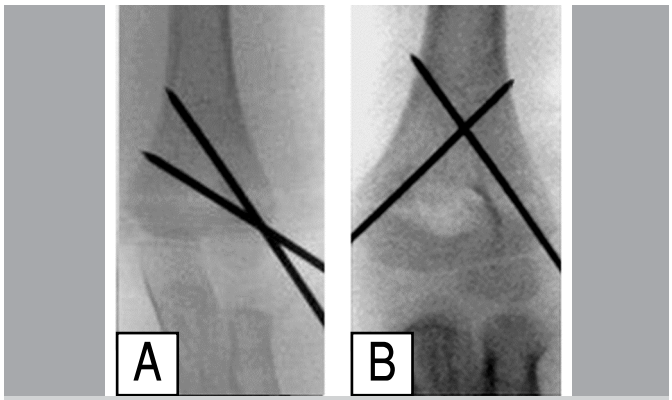

Figure 3. Illustration of the two types of fixation evaluated. A: Two divergent lateral Kirschner wires inserted through the lateral epicondyle; B: Two Kirschner wires crossed above the fracture inserted through the epicondyles.

The exit end of the pins was left out of the skin and folded to be removed after X-ray in three weeks. Still in the surgical environment, after final confirmation of the reduction and fixation (front, side, and oblique incidence to visualize the positioning of the wires, the two columns, as well as stability test with arm rotation), an axillopalmar splint cast was applied with the elbow held at 90° angle of flexion and neutral rotation of the forearm. The first evaluation was performed after one week, then in three weeks for removal of Kirschner wires (after radiography without the splint), and in the fourth week to remove the immobilization and guide home physiotherapy. There was a new evaluation after one month and, finally, in six months. Intermediate evaluations were performed in cases of nerve injury due to fracture or difficulty in gaining movement. In the last evaluation, we measured the frontal alignment and the range of motion of both elbows and applied the Flynn criteria,[8] as described in Table 1.

Chart 1. Flynn clinical criteria[8] for evaluating the outcome of treatment.

Outcome	Result	Cosmetic Factor (Loss of carrying angle, in degrees)	Functional Factor (Loss of range of motion, in degrees)
Satisfactory	Excellent	0 – 4.9	0 – 4.9
	Good	5 – 9.9	5 – 9.9
	Fair	10 – 14.9	10 – 14.9
unsatisfactory	Poor	≥ 15	≥ 15

In the final evaluation, both elbows were radiographed to obtain the Baumann angles (64° to 81°)[9] and the humeral capitellar angle (45° to 57°),[10] as illustrated in Figure 4.

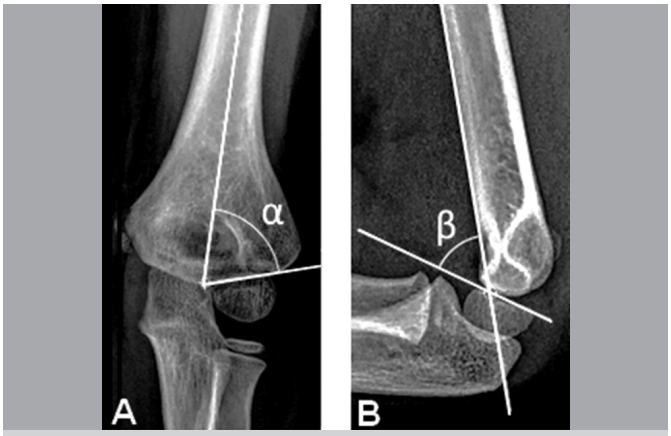

Figure 4. Radiographic parameters used for evaluation of elbows. A: The Baumann angle is formed by the intersection between the longitudinal line of the humerus and a line tangential to the growth plate of the capitellum; B: The humeral capitellar angle is formed by a line tangential to the anterior surface of the humerus and another line tangential to the growth plate of the capitellum.

Grouping

Two groups were formed: 1) Fixation with two crossed Kirschner wires; 2) Fixation with two lateral Kirschner wires. As in each group the fractured side was compared with the respective normal side, there were two subgroups (crossed wireds *x* normal side and lateral wires *x* normal side).

Statistical analysis

Comparisons were made between the two fixed groups with each other and, in each treated group, with the other non-fractured elbow (statistical significance was ≤ 0.05). In the normal distribution (Shapiro-Wilk test), we used comparisons of numerical variables, ANOVA and the *t* test for independent samples and paired samples. In the nonparametric distribution, we used the Mann-Whitney test and Spearman's correlation. The chi-square (χ^2) test was used for categorical variables. The program SPSS v.22.0 (IBM Statistical Package for Social Sciences, United States) was employed.

RESULTS

We evaluated 43 patients, 28 boys (65%) with mean age of six years and five months and 15 girls (35%) with mean age of five years and seven months. All fractures were of the extension type, 28 of them (65%) with posteromedial displacement and 15 (35%) with posterolateral displacement. There was no significant difference between the groups regarding age (p = 0.45), sex (p = 0.33) and initial fragment displacement (p = 0.62).

In 24 cases, fixation was performed with lateral wires (56%), and in 19 cases with crossed wires (44%). Four patients had nerve injury in the first instance of service (one ulnar nerve, two median nerves and two radial nerves), which regressed completely and spontaneously. There was no compartment syndrome, vascular injury, treatment-related nerve injury, or pin infection.

Flexion was slightly smaller in the group fixed with crossed wires, compared with the group fixed with lateral wires (p = 0.04), but close to the subgroups (p = 0.12). There was no difference in extension capacity when comparing patients treated with lateral and crossed wires (p = 0.10), or with the unfractured side (p = 0.89). The recovery of extension occurred on average eight weeks after the removal of immobilization. The carrying angle was similar in the comparison between the fractured and the unfractured side, in both types of fixation (p = 0.94).

The Baumann angle was not significantly different between the two types of fixation (p = 0.79). When the comparison was made in relation to the non-fractured side, the two types of fixation presented slightly larger numbers (p = 0.01), which shows a slight residual deviation in varus. The humeral capitellar angle was slightly greater in patients treated with lateral wires (p = 0.08) in relation to crossed wires, but there was no significant difference compared to unfractured elbows (p = 0.62).

The results, according to Flynn criteria, are shown in Figure 5, with no significant difference between the two treatment methods when compared with each other, or with the unfractured sides (p = 0.56).

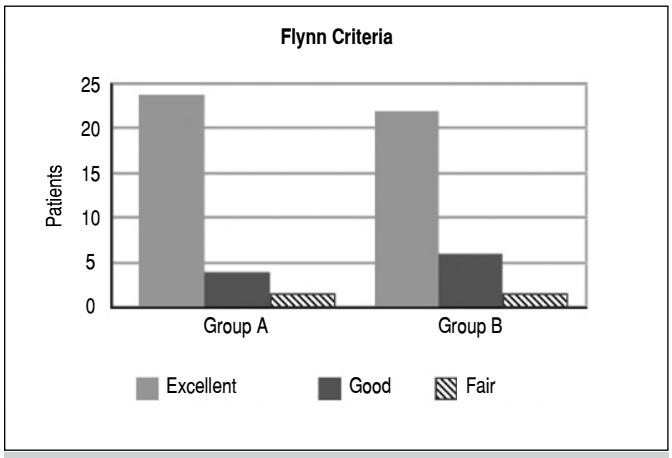

Figure 5. Outcome of the results according to the Flynn criteria.[8] Group A represents patients treated with two crossed wires, while Group B represents patients treated with lateral fixation.

DISCUSSION

Supracondylar fracture of the humerus in children is a commonly studied condition in pediatric orthopedic traumatology. However, several existing publications have a retrospective design and some biases. Our study was randomized and prospective, in addition to using the unfractured elbow for comparison.

The fracture under study results from the weakening of the supracondylar region of the humerus, because in children the cartilaginous component at the end of the elbow is large, associated with the fact that there is overlap of the olecranon and coronoid fossae. The end of the humerus is supported by two bone columns, which are more fragile in the growing bone. Supracondylar fracture occurs more frequently in children with greater ligament looseness, especially in those with physiological antecurvature of the elbow. This causes the elbow to have forced hyperextension when one falls with support on the flat hand, favoring posterior displacement. The same trauma in children without increased ligament looseness tends to cause fracture of the distal end of the forearm.[11]

This fracture is one of those with the greatest potential for acute (neurovascular) or late (vicious consolidation) complications. In addition, unlike what occurs in other fractures of the immature skeleton, it has a small capacity for remodeling.[12] Therefore, the definitive reduction should be anatomical and the fixation maintained until the formation of a stable bone callus, which occurs between three and four weeks.[13]

Some therapeutic approaches are already well established for these fractures, such as the need for proper reduction and fixation, because they are potentially unstable, since the distal fragment is relatively small, the elbow joint is close and the fracture occurs in a flattened region of the bone, which causes that there is little contact area between the fragments. The most frequent vicious consolidation is in varus and may occur due to insufficient initial reduction, or loss of the reduction obtained. The latter possibility is controlled by proper fixation. Classically, vicious consolidation in varus was seen as a purely aesthetic problem. However, it was observed that this deviation in the adult population may cause rotatory instability,[14] late ulnar neuropathy,[15] snapping triceps syndrome,[16] or progressive varus in the ulna.[17]

Even if only deformity is considered, it is in a habitually exposed region, there is a compromise of self-image, which can lead to loss of self-esteem and psychological difficulties.

Our analysis shows that both fixation configurations studied here presented good results and that, using the purely clinical parameters, there was no difference between the two techniques, and there was no significant difference between the fractured elbow and the contralateral elbow. This is especially important because when extending the elbows it is intuitive to compare the alignment between them. The radiographic parameters of the fractured and control groups showed that Baumann angle was statistically similar in the elbows fixed with lateral and crossed wires; however, it was smaller compared to the unfractured side, which means slight residual deviation in varus. The comparison of these angles with the normal elbow is very important because their physiological variations are large. On the other hand, the comparison of the humeral capitellar angle showed that the elbows treated with lateral wires showed a slight anterior deviation in relation to the crossed wires.

In our series there was no iatrogenic lesion of the ulnar nerve, a care that should be reinforced since between 5.7% and 17.7% of children may present anterior subluxation of this nerve, with elbow flexion,[18] which favors a possible migration of the nerve and injury in the introduction of the medial wire. Since, from a technical point of view, fixation with only lateral wires is simpler and with less risk of nerve injury, it may be preferred for common fractures. Since crossed wires provide more stability,[5] they could be reserved for the most unstable fractures, such as those with medial comminution, or with multidirectional instability that results from the rupture of the entire periosteal wrap, but these particularities were not investigated in our study. In addition, in our methodology, we did not compare the images of the immediate surgical reduction with those after the fracture consolidation, which does not allow the assessment of a possible loss of reduction.

As limiting factors in our investigation, we highlight the relatively small number of cases, although this was compensated by the prospective methodology, by the randomization and homogeneity of the sample. In addition, we did not evaluate the possibility of reduction loss and rotational deviation, which is of little importance in terms of function, but may compromise the stability of fixation. By decreasing the contact between the fragments and making it difficult to locate the wires properly.

In summary, our analysis shows that the two types of fixation of the supracondylar humeral fracture present similar clinical outcomes. One difference is that with crossed wires there was smaller extension, but the evolution of this finding would require longer follow-up time. Because fixation with crossed wires is technically more difficult and potentially more dangerous for ulnar nerve injury, it could be left as a secondary choice for fractures that are more severe, unstable and with significant displacement, which means major periosteal injury.[5]

CONCLUSION

Both types of supracondylar fracture fixation presented similar clinical outcomes and there was no significant change in the frontal alignment of the elbow or function compared to the unfractured side.

AUTHORS' CONTRIBUTION: Each author contributed individually and significantly to the development of this article. HMN: acquisition, analysis and interpretation of data, writing; SCSS: aid in the acquisition and analysis of data; JBV: conception and design of the study, critical review of its intellectual content and final approval of the manuscript.

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EXTRACORPOREAL SHOCKWAVE THERAPY IN SHOULDER INJURIES: PROSPECTIVE STUDY

USO DE TERAPIA DE ONDAS DE CHOQUE EM DOENÇAS ORTOPÉDICAS DO OMBRO: ESTUDO PROSPECTIVO

Victor Otavio Moraes de Oliveira[1], *Juliana Munhoz Vergara*[1], *Vicente Furquim de Oliveira*[1], *Paulo Henrique Schmidt Lara*[1], *Luiz Carlos Nogueira Júnior*[1], *Gustavo Gonçalves Arliani*[1]

1. Orthopedics and Traumatology Group of Prevent Senior, São Paulo, SP, Brazil.

ABSTRACT

Objective: To evaluate the functional results after the use of extracorporeal shockwave therapy (ESWT) in four groups of patients: tendinopathy, partial rotator cuff injury, adhesive capsulitis and calcareous tendinopathy of the rotator cuff at one month and three months after the end of treatment. Methods: Case series in which patients were evaluated according to the VAS of pain, range of motion of the shoulder, and functional questionnaires DASH and modified UCLA. Results: There was a significant increase in the measure of flexion, lateral rotation and shoulder abduction in the evaluations after treatment in relation to the baseline measurement ($p < 0.001$) and no evidence of significant difference was found between the post-treatment evaluations at one month and three months follow-up ($p > 0.05$). There was a significant reduction in the VAS score, increase in the UCLA score and a significant reduction in the DASH score in the post-treatment evaluations in relation to the baseline score ($p < 0.001$) and a significant improvement in the three-month evaluation in relation to one month ($p < 0.05$). Conclusion: Extracorporeal shockwave therapy proved to be efficient and safe in the treatment of shoulder pathologies, improving pain, range of motion and functional scores in all groups of patients evaluated in the study. ***Level of Evidence IV, Case series.***

Keywords: Shoulder Injuries. Shoulder. Extracorporeal Shockwave Therapy.

RESUMO

Objetivo: Avaliar os resultados funcionais após uso de terapia de ondas de choque (TOC) em quatro grupos de pacientes: tendinopatia, lesão parcial de manguito rotador, capsulite adesiva e tendinopatia calcária do manguito rotador com 1 mês e 3 meses após término do tratamento. Métodos: Série de casos, na qual os pacientes foram avaliados de acordo com a EVA da dor, amplitude de movimento do ombro, e questionários funcionais DASH e UCLA modificados. Resultados: Houve aumento significativo das medidas de flexão, rotação lateral e abdução do ombro nas avaliações após tratamento, em relação à medida basal ($p < 0,001$) e não houve evidências de variação significativa entre as avaliações pós-tratamento com 1 mês e 3 meses de acompanhamento ($p° > 0,05$). Houve redução significativa do escore EVA, aumento do escore UCLA e redução significativa do escore DASH nas avaliações após tratamento em relação ao escore basal ($p < 0,001$) e melhora significativa na avaliação de três meses em relação a um mês ($p < 0,05$). Conclusão: A terapia de ondas de choque mostrou-se uma terapia eficiente e segura no tratamento das patologias do ombro, com melhora da dor, arco de movimento e escores funcionais em todos os grupos de pacientes avaliados no estudo. ***Nível de Evidência IV, Série de casos.***

Descritores: *Lesões do Ombro. Ombro. Tratamento por Ondas de Choque Extracorpóreas.*

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INTRODUCTION

Pain complaints that affect the shoulder girdle region are common causes of orthopedic appointments.[1] Among the most common diseases, we mainly have conditions that affect the rotator cuff, such as tendinopathies, partial rotator cuff injuries, calcareous tendinopathies, and adhesive capsulitis.[2] Conservative treatment with medications, physical therapy, acupuncture, anesthetic blocks, and corticosteroid injections is usually the initial treatment and is effective in most cases.[3,4] However, patients resistant to primary treatment are not always willing or in good clinical condition for surgical treatment, which, in turn, does not always guarantee good results.

The use of alternative therapies, such as shockwave therapy, has been reported with good results in certain groups of patients.[5-8] However, there is still no consensus in the literature about protocols and specific diseases where shockwave therapy is effective. The use of shockwave therapy applied to the musculoskeletal system in Brazil began in 1998 with the arrival of the first urological lithotripsy machines, which were adapted

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The study was conducted at the Orthopedics Institute of Prevent Senior.
Correspondence: Paulo Henrique Schmidt Lara. Rua José Oscar de Abreu Sampaio, 368, São Paulo, SP, Brazil, 03337020. phslara@gmail.com

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for use in orthopedic injuries. This adaptation consisted in the introduction of a new technology that allowed to grade the depth and force with which shock waves penetrate the human body.[5] The action is determined by the penetration of mechanical waves into tissues, without damage to the skin, vessels and nerves. Upon reaching the injured site, the shock waves promote a mechanical stimulus that induces a series of biological effects, such as: increased production of prostaglandins related to the tissue repair process; increased congestion and local blood microcirculation and increased local nitric oxide concentration with pain relief.[9-12] Thus, the aim of this study is to evaluate the functional outcomes after the use of shockwave therapy (SWT) in four groups of patients: tendinopathy, partial rotator cuff injury, adhesive capsulitis, and rotator cuff calcareous tendinopathy with one month and three months after the end of treatment.

MATERIALS AND METHODS

This is a prospective study with four groups of patients with the following diseases: 1. Rotator cuff tendinopathy; 2. Shoulder adhesive capsulitis; 3. Calcareous tendinopathy of the shoulder; 4. Partial rotator cuff injury. The Study was submitted and approved by the institution's research ethics committee (number 27245219.8.0000.8114). All patients over 18 years of age were selected from the general orthopedic and shoulder clinic of Prevent Senior and treated between 01/01/2018 and 04/30/2018, with diagnoses confirmed by imaging exams (radiographs, ultrasonography and/or magnetic resonance), who have failed conventional conservative treatment for at least three months. The patient sample was estimated using a 95% confidence interval and 80% power to detect a 15-point difference in the DASH score, with a standard deviation of 10 to 18 in each group and allowing a loss of approximately 20% of patients. In this way we recruited a total of at least 15 individuals in each group.

Patients were evaluated according to the VAS[13] (visual analogue scale) of pain, range of motion (anterior elevation, medial rotation, lateral rotation and abduction) of the shoulder, and functional DASH[14] and modified UCLA questionnaires.[15] Three shockwave therapy sessions were carried out in each patient, with an interval of seven days each, and reassessments after one and three months after the last session. The shockwave therapy sessions were performed by three physicians with prior training in the technique and members of the Brazilian Medical Society of Shockwave Therapy (SMBTOC). All sessions were performed by the same physician.

Inclusion criteria

- Patients over 18 years old, without distinction of age or gender;
- Present a diagnosis of rotator cuff tendinopathy or partial lesion that affects less than 50% of the thickness or adhesive capsulitis or rotator cuff calcareous tendinopathy;
- Diagnostic confirmation through magnetic resonance;
- Availability of follow-up during the study period (three months);
- Having undergone previous conservative treatment without improvement of symptoms for a minimum period of three months;
- Having signed an informed consent form to participate in the study (Annex 5).

Exclusion criteria

- Previous surgery on the affected shoulder;
- Injury greater than 50% of the thickness of the rotator cuff;
- Adhesive capsulitis secondary to fracture of the shoulder girdle;
- Secondary osteoarthritis;
- Treatment with corticosteroids in the last two months.

Statistical analysis

Descriptive statistical analysis of each of the analyzed parameters was performed. Parametric statistical tests were used, as the data are quantitative and continuous. To compare the quantitative variables, the ANOVA test was used. Differences with $p < 0.05$ were considered to be statistically significant.

RESULTS

The study sample consisted of 60 patients, of which 6 (six) abandoned the study before the evaluation one month after the first application. Of these six patients, one underwent surgical treatment due to the lack of improvement in the partial cuff lesion before completing the three-month follow-up. The remaining patients (five) started the shockwave therapy, but before the end of the three sessions, they chose to continue with the conservative treatment with medication and physical therapy. We did not observe side effects and complications related to the technique in the patients included in the study. Thus, the results observed in 54 patients with shoulder injury treated with Shockwave Therapy, with first application between May and August 2018, were analyzed.

Participants (Table 1) were aged between 51 and 92 years, with a mean of 63.6 years (SD = 7.5 years). The diagnoses and duration of symptoms before the beginning of the study and the presence of comorbidities of the patients are also shown in Table 1.

Table 1. Characteristics of patients with shoulder injury treated with Shockwave Therapy.

Age (years)	n = 54
mean (SD)	63.6 (7.5)
median (Q1; Q3)	62 (58; 67)
minimum, maximum	51; 92
Age group	
50 to 59 years	17 (31.5%)
60 to 69 years	28 (51.9%)
70 years or older	9 (16.7%)
Gender	
Male	13 (24.1%)
Female	41 (75.9%)
Diagnostic	
MR tendinopathy	12 (22.2%)
MR partial injury	18 (33.3%)
Adhesive capsulitis	12 (22.2%)
Calcific tendonitis	12 (22.2%)
Affected side	
Right	34 (63.0%)
Left	20 (37.0%)
Dominance	
Right	51 (94.4%)
Left	3 (5.6%)
Symptoms time	
3 to 6 months	9 (16.7%)
6 to 12 Months	16 (29.6%)
12 to 24 months	16 (29.6%)
more than 24 months	13 (24.1%)
Comorbidities	
Yes	48 (88.9%)
No	6 (11.1%)
Surgery	
No	54 (100.0%)

SD: standard deviation; Q1: first quartile; Q3: third quartile.

Patients were evaluated for range of motion measurements at baseline, one month and three months after treatment (Table 2).

Table 2. Estimated mean values and confidence intervals (95%CI) during follow-up for the range of motion measurements of patients with shoulder injury treated with Shockwave Therapy.

Range of Motion (RM)	Evaluation		
	Baseline (n = 54)	1 month (n = 54)	3 months (n = 54)
Previous elevation (°)	121.9 (112.9; 131.7)	143.7 (135.3; 152.7)	145.7 (137.4; 154.6)
Differences			
1 month – Baseline	21.8 (12.7; 30.9)	p < 0.001	
3 months – Baseline	23.8 (13.4; 34.2)	p < 0.001	
3 months – 1 month	2.0 (-4.4; 8.5)	P = 0.536	
Lateral rotation (°)	53.5 (48.4; 59.1)	63.3 (58.0; 69.1)	64.4 (58.9; 70.3)
Differences			
1 month – Baseline	9.8 (2.0; 17.7)	p = 0.010	
3 months – Baseline	10.8 (2.8; 18.9)	p = 0.004	
3 months – 1 month	1.0 (-2.3; 4.4)	p = 0.550	
Abduction (°)	72.1 (67.9; 76.6)	83.6 (81.1; 86.2)	85.0 (82.6; 87.4)
Differences			
1 month – Baseline	11.5 (6.4; 16.6)	p < 0.001	
3 months – Baseline	12.9 (7.4; 18.3)	p < 0.001	
3 months – 1 month	1.4 (-0.6; 3.4)	p = 0.179	

Values expressed as estimated means and 95% confidence intervals; p values corrected by the sequential Bonferroni method.

We found evidence of a significant increase in the measurement of anterior elevation, lateral rotation and shoulder abduction in the post-treatment assessments compared to the baseline measurement ($p < 0.001$) and there was no evidence of significant variation between the post-treatment assessments at one month and three months follow-up ($p > 0.05$).
Pain and function assessment instruments were applied to patients at baseline, one month and three months after treatment (Table 3).

Table 3. Estimated mean values and confidence intervals (95%CI) during follow-up for pain and function scores of patients with shoulder injury treated with Shockwave Therapy.

Instrument scores	Evaluation		
	Baseline (n = 54)	1 month (n = 54)	3 months (n = 54)
VAS	6.9 (6.4; 7.4)	4.8 (4.1; 5.5)	3.4 (2.7; 4.1)
Differences			
1 month – Baseline	-2.1 (-2.9; -1.3)	p < 0.001	
3 months – Baseline	-3.5 (-4.4; -2.7)	p < 0.001	
3 months – 1 month	-1.4 (-2.1; -0.8)	p < 0.001	
UCLA	43.3 (40.3; 46.6)	69.0 (64.7; 73.6)	74.6 (68.9; 80.8)
Differences			
1 month – Baseline	25.7 (20.4; 30.9)	p < 0.001	
3 months – Baseline	31.3 (24.9; 37.6)	p < 0.001	
3 months – 1 month	5.6 (0.8; 10.5)	p = 0.024	
DASH	57.3 (53.3; 61.6)	40.5 (35.5; 46.3)	34.1 (28.8; 40.3)
Differences			
1 month – Baseline	-16.8 (-22.8; -10.7)	p < 0.001	
3 months – Baseline	-23.2 (-30.0; -16.4)	p < 0.001	
3 months – 1 month	-6.4 (-11.9; -1.0)	p = 0.021	

Values expressed as estimated means and 95% confidence intervals; p values corrected by the sequential Bonferroni method.

We observed evidence of a significant reduction in the VAS score, an increase in the UCLA score and a significant reduction in the DASH score in the post-treatment assessments compared to the baseline score ($p < 0.001$) and a significant improvement in the three-month evaluation compared to the one-month evaluation ($p < 0.05$).
We investigated the relation between VAS scores at baseline, one month and three months after treatment, and patient characteristics (Table 4).

Table 4. Estimated mean values and confidence intervals (95%CI) during follow-up for the VAS score according to the characteristics of patients with shoulder injury treated with Shockwave Therapy.

VAS score Characteristics of patients	Evaluation		
	Baseline	1 month	3 months
Gender			
Male	6.7 (5.7; 7.7)	4.2 (3.0; 5.4)	2.9 (1.4; 4.5)
Female	7.0 (6.4; 7.5)	5.0 (4.1; 5.8)	3.5 (2.7; 4.3)
Comparisons			
Male × Female	p = 0.649	p = 0.331	p = 0.506
Age group			
50 to 59 years	6.7 (5.9; 7.5)	4.5 (3.3; 5.8)	3.2 (1.9; 4.5)
60 to 69 years	7.1 (6.5; 7.7)	4.9 (3.9; 5.8)	3.8 (2.8; 4.8)
70 years or older	6.7 (5.1; 8.3)	4.9 (3.4; 6.4)	2.3 (1.2, 3.4)
Comparisons			
50-59 a × 60-69 a	p > 0.999	p > 0.999	p = 0.598
50-59 a × ≥ 70 a	p > 0.999	p > 0.999	p = 0.598
60-69 a × ≥ 70 a	p > 0.999	p > 0.999	p = 0.179
Diagnostic			
MR tendinopathy	6.8 (5.6; 7.9)	5.0 (3.5; 6.5)	3.1 (1.6; 4.6)
MR partial injury	6.9 (6.0; 7.9)	4.4 (3.4; 5.4)	3.2 (2.3; 4.2)
Adhesive capsulitis	6.3 (5.8; 6.7)	4.3 (2.6; 6.1)	2.8 (1.4; 4.1)
Calcific tendonitis	7.6 (6.6; 8.6)	5.6 (4.4; 6.8)	4.5 (2.6; 6.4)
Comparisons			
MR tendinopathy × MR partial lesion	p > 0.999	p > 0.999	p > 0.999
MR tendinopathy × Adhesive capsulitis	p > 0.999	p > 0.999	p > 0.999
MR tendinopathy × Calcareous tendinitis	p > 0.999	p > 0.999	p > 0.999
MR partial lesion × Adhesive capsulitis	p > 0.999	p > 0.999	p > 0.999
MR partial lesion × Calcareous tendinitis	p > 0.999	p = 0.849	p > 0.999
Adhesive capsulitis × Calcareous tendinitis	p > 0.119	p > 0.999	p = 0.856
Symptoms Time			
3 to 6 months	6.2 (5.1; 7.4)	3.6 (2.2; 4.9)	3.0 (1.4; 4.6)
6 to 12 months	6.8 (5.9; 7.7)	4.6 (3.4; 5.7)	3.1 (1.8; 4.4)
12 to 24 months	7.1 (6.3; 7.9)	5.8 (4.4; 7.1)	3.0 (1.9; 4.1)
more than 24 months	7.2 (6.2; 8.3)	4.7 (3.4; 6.0)	4.4 (2.8; 6.0)
Comparisons			
3-6 m × 6-12 m	p > 0.999	p = 0.975	p > 0.999
3-6 m × 12-24 m	p > 0.999	p = 0.158	p > 0.999
3-6 m × > 24 m	p > 0.999	p = 0.975	p > 0.999
6-12 m × 12-24 m	p > 0.999	p = 0.933	p > 0.999
6-12 m × > 24 m	p > 0.999	p = 0.975	p > 0.999
12-24 m × > 24 m	p > 0.999	p = 0.975	p = 0.999

Values expressed as estimated means and 95% confidence intervals; p values corrected by the sequential Bonferroni method

We observed that in all the diseases studied there was an improvement in VAS. In rotator cuff tendinopathy, there was an improvement from 6.8 to 3.1 at the end of the follow-up. In the partial rotator cuff injury, there was an improvement from 6.9 to 3.2 at the end of the follow-up. In the adhesive capsule there was an improvement from 6.3 to 2.8 at the end of the follow-up. In calcareous tendinitis there was an improvement from 7.6 to 4.5 at the end of the follow-up. We found no significant differences in mean VAS scores at baseline, one month and three months after treatment, between male and female, age, diagnostic, and symptom time groups ($p > 0.05$ in all comparisons in the three evaluations).

Table 5 shows the relationship between UCLA scores at baseline, one month and three months after treatment, and patient characteristics.

Table 5. Estimated mean values and confidence intervals (95%CI) during follow-up for the UCLA score according to the characteristics of patients with shoulder injury treated with Shockwave Therapy.

UCLA score Characteristics of patients	Evaluation		
	Baseline	1 month	3 months
Gender			
Male (n = 13)	45.1 (38.9; 52.2)	72.3 (64.9; 80.6)	80.0 (70.5; 90.8)
Female (n = 41)	42.8 (39.3; 46.5)	67.9 (62.9; 73.4)	72.9 (66.2; 80.3)
Diagnostic			
MR tendinopathy (n = 12)	41.2 (34.6; 49.0)	69.8 (61.1; 79.6)	74.3 (61.9; 89.3)
MR partial lesion (n = 18)	44.4 (39.8; 49.6)	73.3 (68.0; 79.1)	80.6 (73.5; 88.5)
Adhesive capsulite (n = 12)	44.5 (38.2; 51.8)	68.8 (57.3; 82.7)	75.0 (64.4; 87.4)
Calcareous tendinitis (n = 12)	42.6 (36.1; 50.3)	61.9 (54.7; 70.1)	65.5 (52.2; 82.2)

Values expressed as estimated means and 95% confidence intervals; p values corrected by the sequential Bonferroni method.

We observed that in all diseases studied there was an improvement in the UCLA score. In rotator cuff tendinopathy, there was an improvement from 41.2 to 74.3 at the end of the follow-up. In the partial rotator cuff injury, there was an improvement from 44.4 to 80.6 at the end of the follow-up. In the adhesive capsule there was an improvement from 44.5 to 75 at the end of the follow-up. In calcareous tendinitis there was an improvement from 42.6 to 65.5 at the end of the follow-up. We found no significant differences in mean VAS scores at baseline, one month and three months after treatment, between male and female, age, diagnostic, and symptom time groups ($p > 0.05$ in all comparisons in the three evaluations).

Table 6 shows the relation between DASH scores at baseline, one month and three months after treatment, and patient characteristics.

We observed that in all diseases studied there was an improvement in the DASH score. In rotator cuff tendinopathy, there was an improvement from 63 to 33.6 at the end of the follow-up. In the partial rotator cuff injury, there was an improvement from 53.2 to 33.5 at the end of the follow-up. In the adhesive capsule, there was an improvement from 58.8 to 29.7 at the end of the follow-up. In calcareous tendinitis there was an improvement from 56.2 to 39.8 at the end of the follow-up. We found no significant differences in mean VAS scores at baseline, one month and three months after treatment, between male and female, age, diagnostic, and symptom time groups ($p > 0.05$ in all comparisons in the three evaluations).

Table 6. Estimated mean values and confidence intervals (95%CI) during follow-up for the UCLA score according to the characteristics of patients with shoulder injury treated with Shockwave Therapy.

UCLA score Characteristics of patients	Evaluation		
	Baseline	1 month	3 months
Gender			
Male	45.1 (38.9; 52.2)	72.3 (64.9; 80.6)	80.0 (70.5; 90.8)
Female	42.8 (39.3; 46.5)	67.9 (62.9; 73.4)	72.9 (66.2; 80.3)
Comparisons			
Male × Female	p = 0.556	p = 0.361	p = 0.260
Age group			
50 to 59 years	47.1 (42.4; 52.2)	69.9 (62.8; 77.9)	75.5 (66.5; 85.7)
60 to 69 years	43.1 (38.7; 48.0)	68.7 (62.5; 75.5)	73.9 (65.7; 83.1)
70 years or older	37.1 (31.2; 44.2)	68.3 (59.2; 78.8)	75.3 (62.4; 90.7)
Comparisons			
50-59 a × 60-69 a	p = 0.287	p > 0.999	p > 0.999
50-59 a × ≥ 70 a	p = 0.048	p > 0.999	p > 0.999
60-69 a × ≥ 70 a	p = 0.287	p > 0.999	p > 0.999
Diagnostic			
MR tendinopathy	41.2 (34.6; 49.0)	69.8 (61.1; 79.6)	74.3 (61.9; 89.3)
MR partial injury	44.4 (39.8; 49.6)	73.3 (68.0; 79.1)	80.6 (73.5; 88.5)
Adhesive capsulitis	44.5 (38.2; 51.8)	68.8 (57.3; 82.7)	75.0 (64.4; 87.4)
Calcific tendonitis	42.6 (36.1; 50.3)	61.9 (54.7; 70.1)	65.5 (52.2; 82.2)
Comparisons			
MR tendinopathy × MR partial lesion	p > 0.999	p > 0.999	p > 0.999
MR tendinopathy × Adhesive capsulitis	p > 0.999	p > 0.999	p > 0.999
MR tendinopathy × Calcareous tendinitis	p > 0.999	p = 0.997	p > 0.999
MR partial lesion × Adhesive capsulitis	p > 0.999	p > 0.999	p > 0.999
MR partial lesion × Calcareous tendinitis	p > 0.999	p = 0.109	p = 0.443
Adhesive capsulitis × Calcareous tendinitis	p > 0.999	p > 0.999	p > 0.999
Symptoms Time			
3 to 6 months	47.6 (43.5; 52.1)	72.1 (65.9; 78.8)	80.0 (66.3; 96.5)
6 to 12 months	43.6 (39.1; 48.5)	75.9 (69.7; 82.7)	81.6 (73.1; 91.1)
12 to 24 months	43.6 (37.1; 51.2)	60.2 (51.7; 70.0)	70.2 (60.8; 81.1)
more than 24 months	39.8 (33.3; 47.5)	69.2 (60.8; 78.9)	67.7 (55.8; 82.1)
Comparisons			
3-6 m × 6-12 m	p > 0.999	p = 0.822	p > 0.999
3-6 m × 12-24 m	p > 0.999	p = 0.186	p = 0.902
3-6 m × > 24 m	p = 0.381	p = 0.822	p = 0.902
6-12 m × 12-24 m	p > 0.999	p = 0.035	p = 0.514
6-12 m × > 24 m	p > 0.999	p = 0.717	p = 0.514
12-24 m × > 24 m	p > 0.999	p = 0.668	p > 0.999

Values expressed as estimated means and 95% confidence intervals; p values corrected by the sequential Bonferroni method

DISCUSSION

Shockwave therapy showed improvement in pain parameters, range of motion and functional scores in relation to the studied shoulder pathologies. In addition, no significant difference was found in the results regarding gender, age, diagnosis and previous time of symptoms, which shows that this is a treatment option that can be used in the vast majority of patients with shoulder conditions, with good results. The use of shock wave therapies in tendinopathies and partial rotator cuff injuries is not a consensus, there is still a lack of quality studies proving their effectiveness in this group of patients.[16] In the study by Chou et al.,[17] there was a significant improvement in the pain scale and functional scores in athlete and non-athlete patients with tendinopathies and partial rotator cuff injuries undergoing treatment with shock waves. In the study by Frizziero et al.,[18] a comparison was made between shockwave therapy and intra-articular hyaluronic acid infiltration for the treatment of rotator cuff tendinopathy, with both showing good results. However, infiltration led to faster results and shockwave therapy led to longer lasting results. Specifically regarding rotator cuff tendinopathy compared to placebo, there are studies showing good results in favor of shockwave therapy,[19,20] while others show similar results between placebo and shockwave therapies.[21,22] In our study, there were good results with statistical significance in relation to shockwave therapy in all groups, although the study does not present a control group.

Regarding capsulitis, the study by Muthukrishnan, Rashid and Al-Alkharji[23] compared shockwave therapy with ultrasound therapy in the treatment of diabetic patients with adhesive capsulitis, and a significant reduction in pain and treatment costs was found in patients undergoing treatment with shock waves. In the study by Chen et al.,[24] there was a comparison between shockwave therapy and the use of oral steroids in the treatment of adhesive capsulitis, with both showing favorable results, with the oral steroid group showing faster results. In our study, there were favorable results both in terms of pain and improvement in functional scores in all evaluated groups.

In relation to calcifying tendonitis, there are a greater number of studies with favorable results. Duymaz and Sindel[25] compared shockwave therapy and physical therapy in the treatment of calcific tendonitis, and there was a better result in the shockwave therapy group in relation to pain, gain in range of motion and improvement in functional score. In the study by Tornese et al.,[10] arm positions were compared (neutral position × hyperextension and medial rotation) during shockwave therapy. In the hyperextension and medial rotation group there was a higher percentage of subtotal or total reabsorption of calcium deposits (66.6% versus 35.3%), which was positively related to clinical outcomes. In this study, patients underwent shockwave therapy sessions with the arm in a neutral position. In accordance with previous studies,[26,27] ours showed an improvement in pain, range of motion and functional scores in patients with calcific tendonitis who underwent treatment with shockwave therapy.

There were good results in the four groups of diseases, both in diseases with few studies that evaluated the use of shockwave therapy as an adhesive capsule and in diseases with a greater number of studies, such as calcareous tendonitis. Another important aspect is that the results were similar in all age groups studied, showing that it is a treatment modality that can be used at different ages. Furthermore, there was no difference in the results regarding the duration of symptoms, which shows that shockwave therapy can be used in both more acute and chronic conditions.

This is the first national study to evaluate shockwave therapy in major shoulder diseases. Our study has some limitations, such as the fact that there is no comparison group (control group), however, in this first study, we wanted to evaluate the response of shockwave therapy in shoulder pathologies and, in the next step, we will carry out the comparative evaluation of this modality with other treatments. Another limitation is the three-month follow-up time, which allows an assessment of the therapeutic response but does not allow to assess whether the improvement is maintained in the long term.

CONCLUSION

Shockwave therapy proved to be an efficient and safe therapy, in the short term, in the treatment of shoulder pathologies, with improvement in pain, range of motion and functional scores in all groups of patients evaluated in the study.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article VOMO: writing, critical review and final approval; JMV: substantial contribution to the patient's data; VFO: data interpretation and shockwave therapy sessions; PHSL: writing, critical review and final approval; LCNJ: data interpretation and shockwave therapy sessions; GGA: critical review and final approval.

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UPDATE ARTICLE
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BENEFITS OF THE WALANT TECHNIQUE AGAINST THE COVID-19 PANDEMIC

BENEFÍCIOS DA TÉCNICA WALANT EM CIRURGIAS DA MÃO FRENTE A PANDEMIA DA COVID-19

Rafael Saleme Alves[1,2], Daniel Alexandre Pereira Consoni[1], Pedro Henrique Oliveira Fernandes[1], Sandra Umeda Sasaki[3,4], Isabella Martins Zaia[5], Sofia Brandão dos Santos[5,6], Monica Akemi Sato[2]

1. Hospital IFOR, São Bernardo do Campo, SP, Brazil.
2. Faculdade de Medicina do ABC, Santo André, SP, Brazil.
3. Hospital Sírio Libanês, São Paulo, SP, Brazil.
4. Universidade de São Paulo, São Paulo, SP, Brazil.
5. Universidade Cidade de São Paulo, São Paulo, SP, Brazil.
6. Faculdade de Ciências Médicas de Santos, Centro Universitário Lusíada, Santos, SP, Brazil.

ABSTRACT

Objective: Evaluate the experience of private and public health services with the WALANT procedure in the COVID-19 pandemic. Methods: This is a retrospective, multicenter longitudinal study gathering cases of hand surgery subjected to the WALANT technique in the Hospitals Dr. Radamés Nardini and IFOR during the COVID-19 pandemic (August 2020). As a parameter, the verbal numerical rating scale for twenty patients referring to the preoperative, intraoperative and postoperative periods was applied. Results: The patients did not feel any pain during surgery, which showed the efficiency of the anesthetic technique in its purpose. Conclusion: The results indicate the WALANT technique as beneficial when facing the COVID-19 pandemic, as the main differential of the technique is that it is applied by a well-trained orthopedic hand surgeon. ***Level of Evidence IV, Case Series.***

Keywords: Local Anesthesia. Covid-19. Epinephrine. Lidocaine. Hand. Carpal Tunnel Syndrome.

RESUMO

Objective: Avaliar a experiência dos serviços privado e público de saúde com o procedimento WALANT frente à pandemia COVID-19. Métodos: Trata-se de um estudo longitudinal retrospectivo, multicêntrico, de casos de cirurgia de mão submetidos à técnica WALANT nos hospitais Dr. Radamés Nardini e IFOR, durante a pandemia da COVID-19, em agosto de 2020. Como parâmetro, foi aplicada a Escala Verbal de Dor para 20 pacientes referente ao pré-operatório, intra-operatório e no pós-operatório. Resultados: Os pacientes não sentiram nenhuma dor durante a cirurgia, tendo a técnica anestésica de mostrado eficaz. Conclusão: Pelas análises, foi possível considerar segura e benéfica a técnica WALANT diante da pandemia da COVID-19, que apresenta o diferencial de ser aplicada por um cirurgião ortopédico especialista em mão bem treinado. ***Nível de Evidência IV, Série de Casos.***

Descritores: *Anestesia Local. Covid-19. Epinefrina. Lidocaína. Mão. Síndrome do Túnel Carpal.*

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INTRODUCTION

The WALANT anesthetic technique (Wide Awake Local Anesthesia no Tourniquet) is an innovation in hand surgery in orthopedics and traumatology services.[1] The technique is performed by an orthopedic surgeon with the patient wide awake and without tourniquet, using local anesthetic technique and lidocaine with epinephrine, which gives anesthetic and vasoconstrictive effect. This technique brings numerous surgical benefits to patients and hospital health services. Operating the patient in a vigil state brings the advantage of checking in real time the result of the surgery in the intraoperative period, in addition to immediately correct any surgical failure. Even with vasoconstrictive effect, the use of epinephrine in extremities proves to be a possible and safe procedure.[1-3]

Besides the primary effect of this anesthetic technique, it brings several benefits for the patient. First, it dispenses with preoperative examinations,[2] being convenient for patients with medical comorbidities,[2,4] because it does not require suspension of continuous-use medications, as well as fasting is not necessary,[4] which makes it an excellent benefit for diabetic patients, avoiding hypoglycemia. Second, it prevents exposure of the patient to anesthetic and sedation effects, reducing complications and adverse effect.

Third, with the patient in a vigil state, it is possible to verify bone stability in the case of the osteosynthesis procedure, as well as the integrity of the suture in the tenorrhaphies, thus evaluating the

All authors declare no potential conflict of interest related to this article.

The study was conducted at the Hospital IFOR and Hospital de Clínicas Dr. Radamés Nardini.
Correspondence: Rafael Saleme Alves. Av. Lauro Gomes, 2000, Vila Sacadura Cabral, Santo André, SP, Brazil, 09060870. rafaelsaleme@yahoo.com.br

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active movements in the intraoperative period[1,3,5,6] with direct and immediate view of the correction of the lesion, if necessary. Finally, it brings less need for postoperative monitorization,[2] discharging the patient 30 minutes after the end of the procedure, which reduces the length of stay in the postoperative care unit.[2]

In general, there is few restrictions for the use of this technique, being restrict only for patients with vascular insufficiency.[5] The associated complications occur during the application, and the patient may report tremors, palpitations, and symptoms of agitation, which can last 26 about minutes,[2] which is how long the medicine takes to reach the maximum vasoconstriction. In addition, it may occur a vasovagal reaction by applying with needle, which is easily reversed by placing the patient in Trendelemburg position.[1,2] If necessary, it is possible to revert its adverse effects by applying the phentolamine antidote.[1,2,7]

This study aimed to report the know-how of the private and public health services concerning the WALANT procedure with regard to COVID-19 pandemic.

The hypothesis of the present study is that the WALANT anesthetic technique is efficient for anesthetize and does not generate pain in patients during the intraoperative period of hand surgery, corroborating to the possibility of evaluating the efficacy of surgery in active movement during the intraoperative period.

METHODOLOGY

A retrospective, multicenter longitudinal study of cases of orthopedic hand surgery subjected to the WALANT anesthetic procedure at *Hospital A* and *Hospital B*, during the COVID-19 pandemic in August, 2020. An objective analysis of the verbal numerical scale in the preoperative, intraoperative, and postoperative period, subjective analysis of the efficacy of surgical repair with active movement of the patient in the intraoperative period, and description of the adverse effect presented were performed. A total of 20 patients with a mean age of 37.52 years (21 to 68 years-old) were included. The inclusion criteria were patients subjected to carpal tunnel release, tenolysis, ganglion cyst removal, De Quervain's release, phalangeal fracture surgery, neurolysis, and tenorrhaphy. Five patients were excluded. The exclusion criteria were patients that did not sign the informed consent form or did not want to make their data available for the study. All patients in the study signed the informed consent form. The study was approved by the Research Ethics Committee. Statistical analysis was performed by review manager 5.4 (RevMan) Core Software for Cochrane Reviews.

RESULTS

The patients reported a mean pain intensity score of 6.6, with a standard deviation (SD) of around 2.35, when assessing the results from the Verbal Numerical Rating Scale (VNRS). This variation occurred due to the variety of lesions presented by the patients.

No patient reported pain during the surgical procedure when asked the VNRS, which resulted in a average of 0.0 for pain intensity with SD around 0.0. For plotting purposes, we adopted the standard deviation as 0.01 in order to impose little interference as possible on the results.

Even with a variation of techniques for each specific case, we proved the effectiveness of the anesthesia in the intraoperative period and the active movement capacity during the intraoperative period for different pathologies.

In the postoperative period, the pain intensity mean reported by the patients was 2.5 in the VNRS with SD of around 2.91.

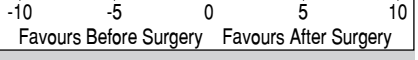
Explicit results were obtained in graphs 1, 2 and 3 when establishing relationships between the VNRS reported in pre- and postoperative period; intra- and postoperative period; and pre- and intraoperative period.

Between the preoperative and postoperative periods, there is a 95% confidence interval with a mean difference of 4.10 [(2.46; 5.74)], a general effect of 4.90, and statistical significance lower than 0.00001.

Between the preoperative and postoperative periods, there is a 95% confidence interval with a mean difference of −2.50 ([−3.78; −1.22]), a general effect of 3.84, and statistical significance lower than 0.0001.

Between the preoperative and postoperative periods, there is a 95% confidence interval with a mean difference of 6.60 [(5.57; 7.63)], a general effect of 12.56 and statistical significance lower than 0.0001.

	Before Surgery			After Surgery			Mean Difference	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI	IV, Fixed, 95% CI
Saleme	6.6	2.35	20	2.5	2.91	20	100.0%	4.10 [2.46, 5.74]	
Total (95% CI)			**20**			**20**	**100.0%**	**4.10 [2.46, 5.74]**	
Heterogeneity: Not applicable									
Test for overall effect: Z = 4.90 (P < 0.00001)									



Graph 1. Assessment of pain: VNRS ratio between preoperative and postoperative of the sample.

	Surgery			After Surgery			Mean Difference	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI	IV, Fixed, 95% CI
Saleme	0	0.01	20	2.5	2.91	20	100.0%	-2.50 [-3.78, -1.22]	
Total (95% CI)			**20**			**20**	**100.0%**	**-2.50 [-3.78, -1.22]**	
Heterogeneity: Not applicable									
Test for overall effect: Z = 3.84 (P = 0.0001)									

Graph 2. Assessment of pain: VNRS ratio between intraoperative and postoperative of the sample.

	Before Surgery			Surgery			Mean Difference	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI	IV, Fixed, 95% CI
Saleme	6.6	2.35	20	0	0.01	20	100.0%	6.60 [5.57, 7.63]	
Total (95% CI)			**20**			**20**	**100.0%**	**6.60 [5.57, 7.63]**	
Heterogeneity: Not applicable									
Test for overall effect: Z = 12.56 (P < 0.00001)									

Graph 3. Assessment of pain: between preoperative and postoperative of the sample.

The most common adverse reaction was palpitation in three patients, being resolved within five minutes after anesthetic application. Only one patient had a vasovagal reaction, which was quickly reversed with the Trendelemburg position.

DISCUSSION

With the COVID-19 pandemic and the need to perform hand and wrist surgeries with WALANT, since there is no sedation,[2] it is possible to perform safe anesthesia without generating aerosol particles. Thus, the hand surgery team of the orthopedic services of the Hospital IFOR and the Hospital de Clínicas Radamés Nardini used the WALANT technique in cases that were convenient, since its applicability has resolution in up to 95% of cases of hand surgery.[8] This local anesthetic technique provides lower-risk of viral dissemination because it does not have the need for ventilation. Moreover, it requires simpler operating rooms,[4] minimum number of professionals, has lower material expenditure, and consequently lower hospital waste production.[8]

In urgent and emergency care services, hand traumatology surgeries require a quick resolution. For example, considering the tendon retractions, the sooner tenorrhaphy is performed, the lower the probability of fibrosis and tenolysis.[4] As well as in cases of bone fracture, the sooner the osteosynthesis is performed, the lower the secondary damage to the patient. In order to support this point, Tang et al.[3] state that in some cities in China, hand surgeons perform open fracture surgery, tenorrhaphies, and nerve repairs in emergency situations shortly after the patient's arrival, being an efficient system considering the anesthetic use of the WALANT technique, which facilitates trauma management and shortly surgical performance with less cost. Besides, Tang et al.[3] state that hand surgeons and the department of anesthesiology have reached a consensus that local anesthesia is the main form of anesthesia for certain hand disorders and an anesthesiologist is not necessary in these cases, a well-trained orthopedic surgeon is sufficient, making the process more quickly to solve the trauma immediately.

Lalonde[4] states that WALANT will soon be the gold standard anesthetic technique for tendon surgeries, as well as for hand, wrist and distal radius fractures.[4] Also, the surgical approach with the wide-awake patient is the success for intraoperative evaluation of the repair, being able to correct and reduce complications in the surgery performance, thus generating greater surgical success. Corroborating the study discussed, the COVID-19 pandemic showed the needs of health services to adapt to the simplest and most advantageous anesthetic techniques. For the hand surgery team, the WALANT technique is the answer to surgical success with regard to the pandemic, also considering the benefits to the patient, post-surgical length of stay, and reduction of the consumption of hospital supplies.

CONCLUSION

That being said, both health services mentioned above used the WALANT anesthetic technique during the COVID-19 pandemic for the performance of necessary hand surgeries, and the difference lies in the anesthesia being applied by the own well-trained orthopedic surgeon. The patients subjected to this technique did not feel any pain during the surgery, proving it to be effective in its purpose. The possibility of evaluating the passive hand movement was a remarkable benefit, enabling greater surgical success and consequently less possibility of surgical re-approach, in addition to shorter post-surgical length of stay, thus, generating greater benefit to the patient's health.

The future perspective is that hand surgery services are able to implement this technique in their daily life due to its benefits.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article. RSA: conception or design of the study, data acquisition, writing and critical review of the content, active participation in the discussion of the results, review and approval of the final version of the study; DAPC: conception or design of the study, data acquisition, critical review of the content, active participation in the discussion of the results, approval of the final version of the study; PHOF: conception or design of the study, data acquisition, critical review of the content, active participation in the discussion of the results, approval of the final version of the study; SUS: conception or design of the study, critical review of the content, approval of the final version of the study; IMZ: conception or design of the study, analysis and interpretation of the data, writing and critical review of the content, active participation in the discussion of the results, review and approval of the final version of the study; SBS: conception or design of the study, analysis and interpretation of the data, writing and critical review of the content, active participation in the discussion of the results, review and approval of the final version of the study; MAS: conception or design of the study, analysis or interpretation of the data, writing or critical review of the content, active participation in the discussion of the results, review and approval of the final version of the study.

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FROM GARRINCHA'S LEGS TO NEYMAR'S LEGS: THE GENU VARUM AND VALGUM IN SOCCER. HISTORICAL OVERVIEW AND UPDATE

DAS PERNAS DE GARRINCHA ÀS DE NEYMAR: OS GENU VARUM E VALGUM NO FUTEBOL. PANORAMA HISTÓRICO E ATUALIZAÇÃO

Fabrício Luz Cardoso[1], *Enrico de Losso Seneme*[1], *Marcos Vinícius Muriano da Silva*[1], *Marcos Henrique Ferreira Laraya*[1], *José Antonio Galbiatti*[2], *Ricardo Hideki Yanasse*[1]

1. Hospital das Clínicas da Faculdade de Medicina de Marília, Serviço de Ortopedia e Traumatologia, Marília, SP, Brazil.
2. Faculdade de Medicina de Marília, Disciplina de Anatomia Humana, Marília, SP, Brazil.

ABSTRACT

The presence of abnormalities in knee alignment (genu varum and genu valgum) is extremely common in soccer. It can occur in the junior league / youth academy and perpetuate itself throughout the professional career. The consequences of years of high-level sports practice in players with genu varum / genu valgum can be harmful to the knees. By observing football matches of the present and the past, the authors of the article noted that great Brazilian soccer players were, or are, affected by the malalignment of the knees: Garrincha (the most famous), Leandro, Dunga, Romário, Rivaldo and Neymar. This study aims to discuss the relationship between high-performance sport and the development of these orthopedic deformities, serving as a tool for updating the trauma-orthopedic knee subspecialty. ***Level of Evidence III, Retrospective comparative study.***

Keywords: Soccer. Genu Varum. Genu Valgum. Bow Legs. Knock Knee.

RESUMO

A presença de anormalidades no alinhamento dos joelhos (geno varo e geno valgo) é extremamente comum no futebol. Seu aparecimento pode ocorrer quando os jogadores estão nas categorias de base e se perpetuar durante a carreira profissional. As consequências de anos de prática esportiva em alto nível em jogadores com geno varo/geno valgo podem ser deletérias aos joelhos. A partir da observação de jogos de futebol do presente e do passado, os autores do artigo notaram que grandes nomes brasileiros deste esporte foram ou são acometidos pelo desalinhamento dos joelhos: Garrincha – o mais famoso –, Leandro, Dunga, Romário, Rivaldo e Neymar. O presente estudo tem como objetivo discutir a relação entre o esporte de alto rendimento e o desenvolvimento dessas deformidades ortopédicas, servindo como ferramenta de atualização da subespecialidade traumato-ortopédica do joelho. ***Nível III de Evidência, Estudo Retrospectivo Comparativo.***

Descritores: *Futebol. Geno Varo. Geno Valgo. Joelhos Arqueados. Perna em Tesoura.*

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INTRODUCTION

Soccer is the most played sport in the world. Data from FIFA, the world's highest soccer entity, show a total estimate of 270 million players around the world in the year 2006.[1] However, this number can be considered to be even higher if we take in account that the last "FIFA Big Count" estimate was done 13 years ago – therefore it is outdated – and that the number of female players has grown and the sport has grown in popularity in recent years.

It is curious to observe that soccer players develop a sort of bowing of their legs, which is commonly nicknamed "pliers legs" or "cowboy legs". It is the so-called *genu varum*. In addition to this angular deformity, another axial deviation that can be found is called *genu valgum*, commonly called "knock knee", where the knees approach each other leaving the legs shaped like an "X". Based on empirical knowledge about the frequent observation of the two aforementioned conditions in soccer players of different nationalities, the objective of this article is to provide a historical account of the manifestation of deformities in well-known soccer players and to update the subject, making this study a tool for updating the knee orthopedic trauma subspecialty.

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The study was conducted at Faculdade de Medicina de Marília.
Correspondence: Fabrício Luz Cardoso. Av. Monte Carmelo, 800, Fragata, Marília, SP, Brazil, 17519030. fabricioramalhense@gmail.com

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MATERIALS AND METHODS

We searched the literature using the MeSH descriptors "Soccer," "*Genu varum*" and "*Genu Valgum*" in the following databases: PubMed, EMBASE, Lilacs, Scopus, Web of Science, SciELO and BVS. Few papers on the subject were found. In addition to the articles, we searched for information about players with *genu varum or valgum* in printed newspapers, audiovisual material, sports websites and historical books. Finally, we resorted to renowned textbooks of anatomy, semiology, orthopedics, sports traumatology and sports medicine, and online material from the UpToDate platform as a basis for the update.

The study was conducted in accordance with the Helsinki Declaration of the World Medical Association on ethical principles for medical research involving human beings, and does not require analysis by the Ethics Committee for Institutional Human Research (CEP).

Anatomy and biomechanics of the knee

The knee joint has three articulations: two articulations between the femur and the tibia (one lateral and one medial) and one articulation between the femur and the patella. Its stability depends on adjacent muscles and their tendons, and the ligaments between the femur and the tibia. The muscles are the main factor of stability.[2]

The knee has an articular capsule made up of an outer fibrous layer and an inner synovial membrane. The femur is located above the fibrous layer, the condyles and the intercondylar fossa are on the posterior side, the tibia is on the lower side and in the anterior portion are the tendon of the quadriceps femoris, the patella and the patellar ligament.[2]

The joint capsule is strengthened by five ligaments: 1) Patellar ligament; 2) Fibular collateral ligament (lateral collateral ligament); 3) Tibial collateral ligament (medial collateral ligament); 4) Oblique popliteal ligament; 5) Arcuate popliteal ligament.[2]

The knee also has intra-articular ligaments. The anterior cruciate ligament (ACL) prevents the posterior detachment of the femur over the tibia and the hyperextension of the joint. The posterior cruciate ligament (PCL) prevents the anterior dislocation of the femur over the tibia or the posterior dislocation of the tibia over the femur and helps prevent hyperflexion of the knee.[2]

There are also two structures in the knee joint that function as "shock absorbers", namely the medial and lateral menisci. They are structures composed of fibrocartilage and absorb mechanical impacts.[2]

There are also the coronary ligaments (they are parts of the joint capsule) and the transverse ligament of the knee that joins the anterior margins of the menisci and fixes them during knee movements.[2]

The most important movements that the knee performs are extension and flexion, although slight rotation also occurs when the knee is flexed. Healthy knees can extend up to 0°. The main muscle involved in this extension process is the quadriceps femoris, and it is most efficient when the hip joint is extended.[2]

The degree of knee flexion depends on the situation of the hip. With the hip extended, the knee reaches 120° of flexion. With the hip flexed, the knee reaches 140°. In addition, the knee can be passively flexed by 160°.[2]

The knee can also perform a medial rotation up to 10° when flexed and 5° when extended. Lateral rotation can reach 30° when the knee is flexed.[2]

Axial deviations of the lower limbs

Etiology and epidemiology

Bow legs and "X-shaped" knees are among the most common musculoskeletal anatomical variations found in health services delivering primary pediatrics care, and they are a common reason for referral to the subspecialty of pediatric orthopedics.[3]

The alignment of the lower extremities undergoes a predictable progression from varum (bow legs), to neutral, to valgum (X-shaped knees) and back to neutral in the first seven years of life.[3,4] The final alignment of adult lower limbs is slightly valgum.[3,4]

Physiological *genu varum* is found between ages 0 and 2; on the other hand, pathological *genu varum* (Blount's disease, also called tibia vara) has two manifestation periods: 1) in children up to 3 years old due to obesity or early walking; 2) in adolescents, with insidious onset in individuals aged 8 or older.[5] Other causes include: nutritional rickets and other metabolic bone diseases, skeletal dysplasia, infection, trauma and neoplasms.[3]

Physiological *genu valgum* occurs between ages 2 and 5 and can be considered pathological when it exceeds the age limit. It is usually caused by bone tumors, but may also have a metabolic cause by renal oestodystrophy or other causes such as trauma (for example, Cozen fracture), mucopolysaccharidosis and infection.[5]

In adulthood, the physiological tibiofemoral angle is 5-7 degrees.[6-8]

Pathophysiology

The law of Hueter-Volkman[9,10], a century and a half ago, postulated that increased pressure parallel to the axis of the epiphysis inhibits growth, while decreased in pressure stimulates growth. In addition, these changes of compressive forces cause asymmetric growth of the joint. Frost's, "Chondral Modeling"[11] theory suggests that physiological load stimulates growth, while larger or smaller loads inhibit growth.

The femur assumes a diagonal position in the thigh, while the position of the tibia in the leg is almost vertical, creating an angle in the knee between the longitudinal axes of these bones clinically called the Q angle.[2] This angle is assessed by drawing a line that goes from the anterior superior iliac spine to the middle of the patella and a second vertical line that runs through the middle of the patella and the tibial tubercle.[2] In its normal anatomy, the angle of the femur in the thigh places the middle of the knee joint directly below the head of the femur in standing position, centralizing the line of weight support in the intercondylar region of the knee.[2]

The medial angulation of the leg relative to the thigh, in which the femur is abnormally vertical and the Q angle is small, causes the emergence of genu varum. Genu valgum occurs due to the lateral angulation of the leg relative to the thigh with a large Q angle (> 17°).[2]

Complications arising from genu varum and genu valgum

Because in genu varum the weight support line is located medially to the center of the knee, there is excess pressure on the medial face of the knee joint, resulting in arthrosis and also exaggerated tension of the fibular collateral ligament.[2] *Genu varum* may also be associated with cavus foot, internal rotation of the tibia, excessive abduction of the hip or external rotation of the hip.[12]

As a result of the excessive angle of the knee in genu valgum, the weight support line is located laterally to the center of the knee, which causes hyperextension of the tibial collateral ligament and excessive tension on the lateral meniscus and cartilages of the lateral condyles of the femur and the tibia.[2] The patella, commonly pulled laterally by the tendon of the vastus lateralis muscle, is pulled even more intensely to the side when the leg is extended in genu valgum, which makes its joint with the femur abnormal.[2] Genu valgum can be associated with flat foot.[12]

Physical examination of the knee for a clinical diagnosis of angular deformities

Didactically, the orthopedic examination of the knee is divided into three stages: inspection (static and dynamic), palpation and specific tests. The most important data for the diagnosis of axial

deviations of the knee comes from the inspection, for which reason this step will be the analyzed in more detailed below.

Inspection (standing patient)

Alignment from head to feet must be observed. The plumb line test can detect abnormalities such as dorsal kyphosis, hyperlordosis, hip flexion or extension or *knee recurvatum*.[13]
In frontal inspection, it is possible to observe and assess lower limb alignment on the same plane (varum and valgum) or on two (torsional deviations), patellar alignment, Q angle, presence of edema, stroke, bruising, muscle atrophies, dynamic changes in the various phases of gait and presence of deformities.[13]
The emergence of latero-lateral deformity (*thrust* or buckling) during the support phase of gait may indicate degenerative arthritis with cartilage erosion and varum deviation of the knee, or peripheral ligament failure associated with anterior cruciate ligament (ACL) injury. *Recurvatum* and limitations to knee extension are revealed at this stage of the examination and can indicate joint blockage or even position resulting from hip flexion deformity.[13]
During static inspection and gait examination, indirect changes are detected that may be related to joint disease, such as abnormal positions of the contracted hip (abduction or adduction).[13]
Gait examination detects lameness, and studying the support time while walking allows the distinction of lameness caused by knee dysfunction or hip dysfunction. Trendelenburg's sign (found in people with weak abductor musculature of the hip) is recognized at this moment of the examination.[13]
The arrangement of the feet and the footprint while walking can change in torsional deformities, especially of the tibia. Patellar alignment should be investigated through the Q angle[13] (normal value between 10 and 15 degrees in men and 15 to 20 degrees in women. When the knee is flexed at 90 degrees, its value corresponds to zero degree).[14] Joint mobility and muscle contours are also evaluated; when different from one side and the other, they can characterize atrophy.[13]

Inspection (sitting patient)

Patellar height is observed. When it is high, it forms an angulation with the patellar ligament, dissociating the quadriceps lever into three arms: the quadriceps muscle of the thigh, the patella and the patellar tendon. Patellar tendon alignment and its insertion in the TAT is also checked. The bayonet sign on the patella or knee occurs due to an increase in the Q angle caused by a torsional deformity with lateral deviation of the TAT.[13]
With the knee extended, the presence of a patellar dislocation at the end of the movement may indicate patellofemoral instability.[13]
If the patient is lying and their knee is flexed at 30°, the bayonet sign on the patella can be detected more easily. The Q angle can also be measured more accurately in this position because the patella is placed entirely in the intercondylar notch.[13]
Flexion and extension of the knee allow assessing the presence of crepitus (initial, terminal and upper) and possible joint pops.[13]

Inspection (patient lying down)

Four movements are assessed: flexion, extension, internal rotation of the tibia and external rotation of the tibia. Physiological flexion and extension range from 0° to 135° of movement and physiological rotation of the tibia ranges from 0° to 15°.[13]

Palpation (patient sitting or lying down)

With the patient in a position that facilitates examination, palpation should be performed in the following sequence: 1) bone structures (upper, middle and lower poles of the patella; tibial tubercles; Gerdy's tubercle; head of the fibula and medial and lateral epicondyls); 2) soft tissues (pre-and infra patellar bursae; joint line; popliteal fossa and tendon insertions).[13]

Specific tests (according to semiotechnics)

The examination proceeds to either special tests, if there is a suspicion of other conditions associated with angular deformities, or to differential diagnosis. The tests are subdivided into: a) menisci tests (McMurray; Appley; Steinmann; Smillie and Trendelenburg gait) and; b) ligament function tests (Lachman or Richey; anterior drawer; posterior drawer; posterolateral drawer; Jerk or rebound; *pivot-shift* or Mclntoch; reverse *pivot-shift* or Jakob's test; RRE – external rotation recurvatum; hyperextension or recurvatum; passive posteriorization of the tibia at 90° or Godfrey; abduction stress or valgum and adduction stress or varum).[13]

Radiographic diagnosis

In a panoramic radiography of the lower limbs, we can observe some anatomical parameters that allow us to distinguish physiological deviations from pathological ones: 1) XR Varum: metadiaphyseal angle of the tibia (MDAT): $< 9°$ is normal, $> 16°$ is pathological/Blount; 2) XR Valgum: alignment in X-ray: in normal adults, valgum is 6 degrees.[5]

Historical context in Brazilian soccer

When we think of players with deformities in lower limb alignment, the picture of the great Brazilian right-hander Mané Garrincha comes to mind (Figures 1 and 2). He was nicknamed "Crooked leg Angel" on account of his noticeable bow legs. According to Ruy Castro's accounts[15]and other newspaper sources,[16-19] Garrincha was born with bone deformities and was subsequently affected by poliomyelitis in his childhood, the sequelae of which aggravated the axial deviations of his lower limbs. His right leg was 6 cm shorter than the left, causing a medial deviation (*genu valgum*) towards the left leg. His left leg also had a similar shape, with a lateral deviation (*genu varum*).[17,19] As a result of that malalignment, Garrincha probably had a dislocated hip and suffered from scoliosis.

Figure 1. Mané Garrincha in Botafogo.

Source: Official Twitter page of Botafogo Futebol e Regatas.[20]

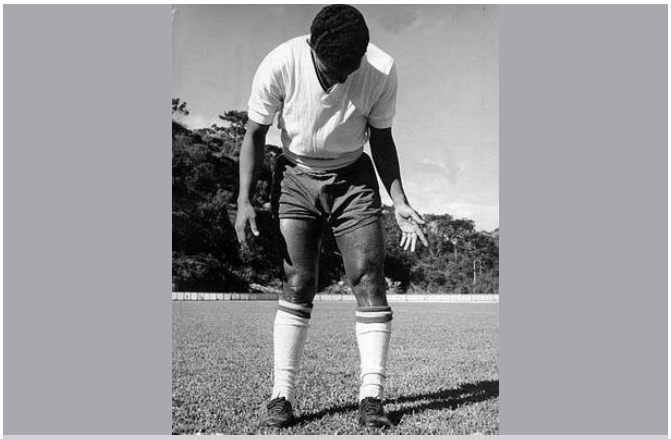

Figura 2. Mané Garrincha looking at his legs.

Source: Agência Estadão.[21]

Another skilled Brazilian player who also has lower limb malalignment is right-back Leandro, who played remarkable seasons for Flamengo and played the 1982 World Cup whit what is regarded as one of the best teams of all time.[22,23] The right back who impressed the world in the squad led by coach Telê Santana had a case of *genu varum*.[22,23] Although his deviation is not as evident as Garrincha's, Leandro even underwent a surgical procedure in an attempt to align his lower limbs, without success.[23]

Following the history of great players in the Brazilian national team, we find that forward Romário, one of the main players in the squad that won the fourth World Cup, also had *genu varum* on his left knee.[18,24] Nicknamed "Baixinho" ("Shortie"), he underwent valgus tibial osteotomy associated with an arthroscopy and as a result became 2 cm taller.[25,26]

Captain of the 1994 world champion squad and former coach of the Brazilian soccer team, Dunga, who played as a midfielder, was also affected by *genu varum* in his left knee. He underwent the same surgical procedures as Romario to align of the axis of his knee and correct meniscal lesions.[27,28]

In the squad that won the fifth world championship, midfielder Rivaldo,[29] who played an important part, had *genu varum* mainly in his right knee.[30] He underwent knee surgery to correct the deformity at age 43 and retired from the sport afterwards.[30]

Although there are not many direct reports on the subject in press sources,[31] one can notice in his performances in matches and training that Neymar Júnior, left-hander of the Brazilian team and one of the main players of world soccer, has a certain degree of bow leg, more noticeable in his left knee (Figure 3).

Figure 3. Neymar Júnior's debut in PSG.

Source: Official Twitter account of Esporte Interativo.[32]

Soccer studies

The etiology of tortuous bones in soccer players seems to be related to tension in the growth phase.[11,33] The growth plates above and below the knee generate most of the growth in leg length and, for geometric reasons, exert the greatest effect on the axis of the legs. The medial tibial growth plate seems to be particularly more vulnerable than the femoral one. Especially in the prepubertal phase of rapid growth, biomechanical overload in the medial proximal physis of the tibia[34] due to trauma or chronic imbalance can lead to asymmetric growth.[33] Cook et al.[34], who proved that the restricted (and, therefore, asymmetrical) growth of the physis due to an excessive compressive load leads to a progressive varum deformity in the knee. Then, an even greater load concentrates in the medial compartment of the knee, as a vicious cycle.[34]

There is also tension of the hamstrings overlapping both growth plates in the knee region, twice as strong in the medial part of the joint as in the lateral part, causing asymmetrical overload in the joints.[33]

The main sporting gestures performed in soccer (professional and junior leagues) are: running, walking, passing, running with changes of direction, disarming (tackling) and kicking. It is not yet known which specific sports gestures can lead to such excessive compressive asymmetrical load of the knee and determine a varum angulation in growing adolescents[35].

It is hypothesized that during dribbling and throwing movements, the adductor muscles of the thigh suffer stress[33] that creates an imbalance between the adductor/abductor muscles. The muscles are then fixed in the medial part of the leg, which increases lateral bone flexion during development, thus generating *genu varum*.[33]

Frequent and repeated contractions on the sartorius, gracilis, semitendinosus and semimembranosus muscles during sport can also contribute to mechanical overload of the medial physis of the proximal tibia.[35]

Besier et al.[36] demonstrated that varum and valgum stress is significantly higher in sprints with change of direction than in a normal sprint. These authors also studied valgum / varum stress in football movements and observed that valgum / varum stress is twice as high in unforeseen situations than in previously planned ones.

Changes in direction cause increased mechanical tension, and as neuromuscular fatigue occurs, dynamic knee stabilization is impaired, and the injury rate increases.[33] One of the main determining factors of distribution from medial to lateral load on the knee occurs during almost the entire support phase of normal gait, in which there is a tendency to abduct the knee. Load sports involving intensive running cause a sharp increase in such moments of knee abduction. According to the Hueter-Volkmann Law[9,10] and Frost's chondral modeling theory,[11] these sharply increased moments of knee abduction during load sports can interrupt the growth of the medial physis of the proximal tibia due to excessive compressive force on the growth plate. This may be a possible explanation for the relationship between load sports and the emergence of varum on the knees of adolescents.[35] In addition, soccer cleats restrict players' external rotation in orthostatic position in the support phase, which stimulates bowing of the legs by increasing the varum load on the knee joint.[33]

It is believed that playing soccer competitively also causes knee varusing, proposing that this occurs as a result of microtraumas of repetition imposed on the internal femoral condyles by exhaustive training.[37] Thaller et al.[33]found in their study that a considerable percentage of athletes have genu varum (55% -63%), which allowed them to conclude that the risk of developing *genu varum* is higher in adolescents who spend much time playing soccer.[33]

This assertion had been previously confirmed via statistics in studies by Witvrouw et.al.,[38] who assessed 336 young Belgian first division

soccer players, compared to the control group with 458 young athletes from other sports, and concluded that soccer players develop *genu varum* more often than the population that does not play soccer. Furthermore, the same study found that soccer players presented genu valgum up to the age group of 12 to 13 years. From the age group of 14 to 15 years, soccer players began to present *genu varum*.[11] Both boys who palyed soccer and boys who did not play soccer, from the age of 16, had *genu varum*. This finding is in agreement with other studies suggesting an evolution in varum in boys past the end of peak growth.[35,38,39]

Thijs et. al.[35] conducted a study comparing 265 healthy Caucasian boys, aged 7 to 18 years, who played competitive sports (athletics, field hockey, basketball, volleyball, tennis, badminton and squash) with another 256 boys with the same biological / age characteristics who had never practiced any sports in their lives, with the exception of sports that they palyed in school for 1 hour. Verifying the occurrence of *genu varum* / *valgum* by measuring intercondylar and intermalleolar distances (CI-IM) and with statistical treatment of the data, the authors[35] concluded that practicing load sports (not only soccer) is significantly related to increased occurrence of *genu varum* in adolescents. Boys who did not play sports presented a negative CI-IM measure (genu valgum) up to the age group of 13-15 years. In the age group of 16-18 years, the CI-MI distance became slightly positive.[35] Boys who played sports showed a negative CI-IM distance until the ages 10-12 years and became positive (*genu varum*) from 13-15 years onwards, with an increasing evolution in the age group 16-18 years.[35]

Colyn et al.[40] argued that most studies on *genu varum* and its relationship with sport used only boys as the object of study and defined the alignment of the knee through the difference between intercondylar and intermalleolar distance (CI-IM). However, the gold standard for this evaluation is a complete leg X-ray (panoramic of lower limbs) since it allows a detailed analysis of the femoral and tibial anatomical parameters and an individual analysis of the right leg and the left leg – a situation that the CI-IM distance does not allow.[40] Using both measurement techniques, the authors[40] conducted a retrospective and prospective study with 100 women and 100 men aged 20 to 27 years (all Caucasians), inquiring them about their sports activities while growing up through three age groups and classifying these activities as low and high level according to the Tegner scale.[41] Standardized full-leg radiographs with weight support were obtained according to Paley and Herzsenberg[42] with the subjects barefoot and the knees fully extended and the patellas facing forward. The x-ray was centered on the knee at a distance of 305 cm.[40] The hip-knee-ankle angle was expressed as a deviation of 180° with a negative value for varum alignment and a positive value for valgum alignment.[40]

Study[40] concluded that: taking part in high activity sports in adolescence is associated with varum alignment at the end of growth in men, but not in women; more pronounced leg bowing was found in soccer players mainly by a significant association with a lower proximal tibial angle; the study did not find differences between the dominant leg (which does the kicking) and the supporting leg of soccer players, therefore the kicking movement does not seem to be decisive in the development of *genu varum*; No significant differences were found between the goalkeeper, defender, midfielder and forward positions.

Abreu, Barbosa and Coelho[37] cite in their study that a large number of soccer coaches prefer adolescent candidates for competitive sport who have varum alignment of the lower limbs as they believe these young palyers to be more skilled.

Chantraine[43] showed in his study that up to 73% of retired football players had *genu varum*.

Regarding complications, professional athletes have an important risk of developing osteoarthritis and this risk is even greater if the athlete has had previous knee injury. There is a strong relationship between the occurrence of *genu varum* and the significant risk of an athlete developing deterioration of articular cartilage in the medial tibiofemoral compartment of the knee, tibiofemoral osteoarthritis, increased chance of injuries to the patellofemoral joint and patellofemoral pain syndrome.[33,38]

Treatment of axial deviations in athletes

Surgical treatment in athletes is not the norm since angular deviations of the lower limbs do not interfere with sports practice and are usually asymptomatic. When there is pain, it is usual to opt for special training measures to improve dynamic stability of the knee, along with modified footwear and adjusted intensity of training for the most vulnerable age group.[3]

In cases where the orthopedic doctor, at his clinical discretion, recommends surgical treatment (usually former athletes with chronic pain), an osteotomy is performed.

Osteotomy of the lower limbs is intended to correct the mechanical axis of the long bones to redistribute the forces in the joint by transferring the load to better preserved areas; to correct deformities or to change the patellofemoral joint mechanics. In an individual with arthrosis (for example, a former soccer player), the main objective of osteotomy is chronic pain relief and functional improvement.[14,44]

In varus knee, the procedure of choice is the proximal valgusing osteotomy of the tibia, where the load is shifted to the lateral compartment and the axial forces in the medial compartment of the knee are reduced – in osteotomies for arthrosis, while in osteotomies associated with treatment of cartilage lesions, the normal procedure is to shift the mechanical axis to the center of the knee. In valgus knee, the procedure performed is the varusing osteotomy of the distal femur, which reduces the load in the lateral compartment and rarely aims for hyper-correction of the mechanical axis. The objective in almost all cases is correction toward the center of the knee.[14,44] Corrections can be performed in the axial, sagittal and /or coronal planes.[14]

CONCLUSIONS

Other studies need to be conducted to clarify the real etiologies and pathophysiological processes related to *genu varum* and *valgum*. The core of such research should be based on the association between soccer practice and development of deformities.

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