Determining Accessibility of Anterior Cervicothoracic Spine Based on Age and Gender: Radiographic Analysis of Computed Tomography Scans

Determinação da capacidade de acesso anterior à coluna cervicotorácica conforme idade e gênero: Análise radiográfica de imagens de tomografia computadorizada

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Abstract

Objective The approachability of the cervicothoracic region anteriorly based on age and gender, and the possibility of anatomic variances in different geographic populations have not been previously investigated. The aim of the present work was to perform a radiographic analysis of Brazilian patients to assess anterior approachability of the cervicothoracic junction based on age and gender.

Methods Retrospective radiographic analysis of 300 computed tomography scans. Patients were separated based on age and gender. The radiographic parameters studied were: horizontal level above the sternum (HLS), vertebral body angle (VBA), intervertebral disc line (IDL), and intervertebral disc line angulation (IDLA).

Results The most frequent HLS and IDL were T2 (34.3%) and C7–T1 (46%) respectively. Vertebral body angleand IDLA had average values of 18 ± 8.94 and 19 ± 7.9 degrees, respectively. Males had higher values in both IDLA ($p = 0.003$) and VBA ($p = 0.02$). Older groups had higher values in both IDLA ($p = 0.01$) and VBA ($p = 0.001$). No differences were observed in HLS between gender ($p = 0.3$) or age groups ($p = 0.79$). No differences were seen in IDL between gender groups ($p = 0.3$); however, the older group had a more caudal level than the younger groups ($p = 0.12$).

Keywords
- spinal diseases
- spinal fusion
- thoracic vertebrae
- tomography, x-ray computed

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Conclusions Compared to other populations, our sample had a more cephalad IDL and HLS. Vertebral body angle and IDLA were higher in males and higher angles for VBA and IDLA were shown for older groups. Intervertebral disc line was more caudal with aging.

Resumo

Objetivo A capacidade de acesso anterior à região cervicotorácica com base na idade e gênero do paciente e a possibilidade de variações anatômicas em diferentes populações geográficas ainda não foram investigadas. O objetivo deste trabalho foi realizar uma análise radiográfica de pacientes brasileiros para avaliar a acessibilidade anterior da junção cervicotorácica conforme idade e gênero.

Métodos Análise radiográfica retrospectiva de 300 tomografias computadorizadas. Os pacientes foram separados por idade e gênero. Os parâmetros radiográficos estudados foram: nível horizontal acima do esterno (HLS, na sigla em inglês), angulação do corpo vertebral (VBA, na sigla em inglês), linha do disco intervertebral (IDL, na sigla em inglês) e angulação da linha do disco intervertebral (IDLA, na sigla em inglês).

Resultados Os HLS e IDL mais frequentes foram T2 (34,3%) e C7–T1 (46%), respectivamente. Os valores médios de VBA e IDLA foram de $18 \pm 8{,}94$ e $19 \pm 7{,}9$ graus, respectivamente. Os homens apresentaram valores maiores de IDLA ($p = 0{,}003$) e VBA ($p = 0{,}02$). Os grupos de maior idade apresentaram valores maiores de IDLA ($p = 0{,}01$) e VBA ($p = 0{,}001$). Não houve diferenças de HLS entre os gêneros masculino e feminino ($p = 0{,}3$) ou faixas etárias ($p = 0{,}79$). Não foram observadas diferenças na IDL entre os gêneros masculino e feminino ($p = 0{,}3$); entretanto, o grupo mais velho apresentou nível mais caudal do que os grupos mais jovens ($p = 0{,}12$).

Conclusões Em comparação a outras populações, nossa amostra apresentou IDL e HLS mais cefálicos. AVBA e a IDLA foram maiores no gênero masculino, enquanto VBA e IDLA foram maiores em grupos mais velhos. A IDL era mais caudal em pacientes idosos.

Palavras-chave
- doenças da coluna vertebral
- fusão vertebral
- vértebras torácicas
- tomografia computadorizada por raios X

Introduction

In spine surgery, the cervicothoracic junction can be a challenging region to reach anteriorly.[1] The most common approach is the anterolateral (Smith-Robinson) approach, permitting treatment of levels as caudal as T2.[2–4] Depending on the relationship of the spine with the sternum and clavicles, this approach can adequately expose intended lower levels without the need for an osteotomy of the sternum or the clavicles.[5–7]

Many techniques, including transsternal, transclavicular and transmanubrial, were described to overcome the bony barriers when approaching the cervicothoracic region. However, higher morbidity and mortality rates are associated with these osteotomies.[8–12] For this reason, preoperative measurements and parameters have been studied to predict whether those osteotomies are necessary during the anterior approach to the cervicothoracic region. Previous studies utilized computed tomography (CT) or magnetic resonance imaging (MRI) of the spine,[3,5,6,13] applying a variety of methods for surgical planning, ranging from a simple disc line passing above the sternum to advanced trigonometry using anatomical reference points.

To date, approachability of the cervicothoracic region anteriorly based on age and gender has not been investigated. Furthermore, no literature exists that has analyzed potential anatomical variances in different geographic populations. The aim of the present study was to perform a radiographic analysis of CT scans of Brazilian patients to assess the anterior approachability of the cervicothoracic junction based on age and gender in this cohort.

Materials and Methods

This was a radiographic study conducted at a single center with approval by the hospital ethics review board. We selected CT scans performed between 2008 and 2014. Inclusion criteria included patients older than 18 years old with normal findings on the CT exam. Exclusion criteria included patients with primary tumor, metastasis, infection, prior spine surgery, sternal fractures and/or requiring sternal procedures. Patients were separated by gender (male and female) and further subdivided by age group (group 1: 18–40 years; group 2: 41–60 years and group 3: older than 60 years), creating 6 groups of 50 exams each, for a total of 300 CT exams. Gender and age were the two clinical parameters acquired from medical records.

Table 1 Parameters measured in the sagittal reconstruction of computed tomography scan

Parameter	Abbreviation	Description
Intervertebral disk line	IDL	Last caudal IDL that passes superior to the sternal notch
Horizontal level above the sternum	HLS	Vertebral body intersected by a horizontal line from sternal notch
Vertebral body angulation	VBA	Angulation of the vertebral body intersected by HLS to a vertical line of the patient
Intervertebral disk line angulation	IDLA	IDA angulation with a horizontal line of the patient

Abbreviations: HLS, horizontal level above the sternum; IDL, intervertebral disc line; IDLA, intervertebral disc line angulation; VBA, vertebral body angulation.

All CT exams were performed in the supine position with the *multislice* Brilliance CT scanner Big Bore Radiology (Koninklijke Philips N.V., Amsterdam, Netherlands) equipment, with 64 channels and 2 mm section cuts. All exams were reviewed by the senior author, Dr. Rafael Lindi Sugino, using the OsiriX MD (Pixmeo SARL, Bernex, Switzerland), which is a software approved by the Food and Drug Administration (FDA), labeled as CE IIa, that allows 3D reconstructions in all planes. All images were reconstructed in all three planes and aligned in all planes for measurement.

Radiographic Evaluation

The following radiologic parameters were studied: 1) horizontal level above the sternum (HLS); 2) vertebral body angulation (VBA); 3) Intervertebral disc line (IDL) and 4) intervertebral disc line angulation (IDLA) (►**Table 1**).

The HLS is the vertebral body that is intersected by a horizontal line starting from the sternal notch. If the line crossed a vertebral disc, the vertebral body considered was always the most caudal one[5] (►**Figure 1**).

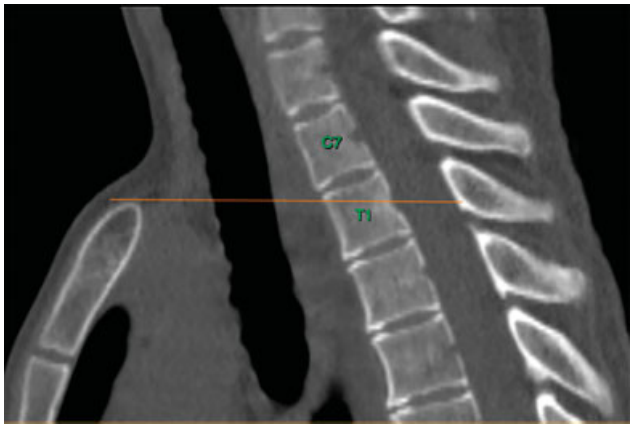

Fig. 1 Horizontal level above the sternum (HLS).

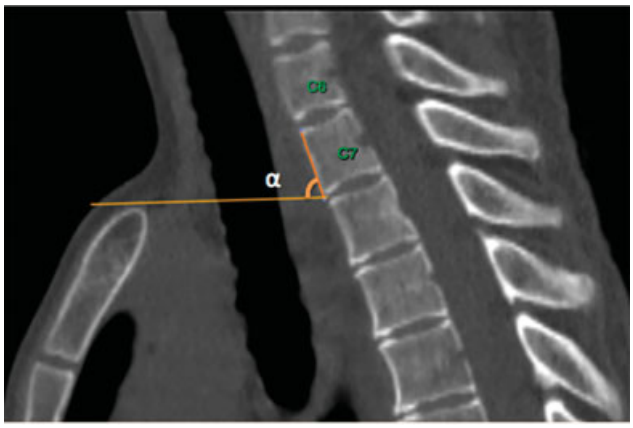

Fig. 2 Vertebral body angulation (VBA) represented by α.

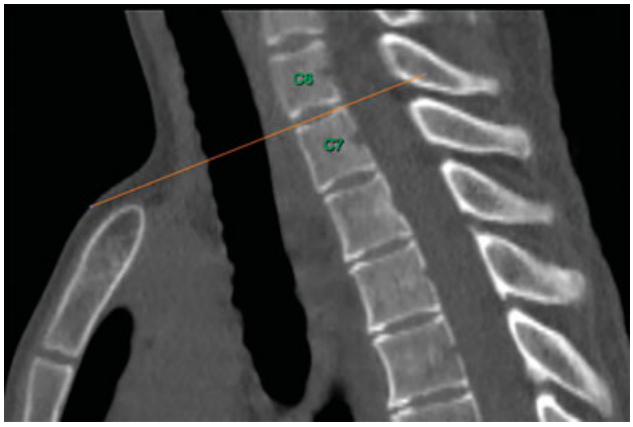

Fig. 3 Intervertebral disc line (IDL).

Once the HLS was determined, the VBA was measured. The angle was measured between a line drawn from the anterior aspect of the vertebral body and a horizontal line starting from the sternal notch. This angulation represents the vertebral rotation if HLS was chosen as a preoperative method (►**Figure 2**).

The IDL is defined by the most caudal intervertebral disc line that crosses above the sternal notch[6] (►**Figure 3**).

Once the IDL was defined, the angulation measured between the IDL and a horizontal line represents the IDLA. This measurement can also be interpreted as a slope angle (►**Figure 4**).

Statistical Analysis

The parametric variables IDLA and VBA are presented with mean and standard deviation values, while the non-parametric variables, IDL and HLS, are presented as percentages.

For the purposes of this study, the clinical data (age and gender) and the non-parametric variables (IDL and HLS) were converted to ordinal variables for statistical analysis.

The parametric variables were submitted for the Shapiro-Wilke test to ensure normal distribution of the data. Histograms, as well as mean and median comparisons, were utilized for this same purpose. Once normal distribution was found, the Student t-test and two-way analysis of

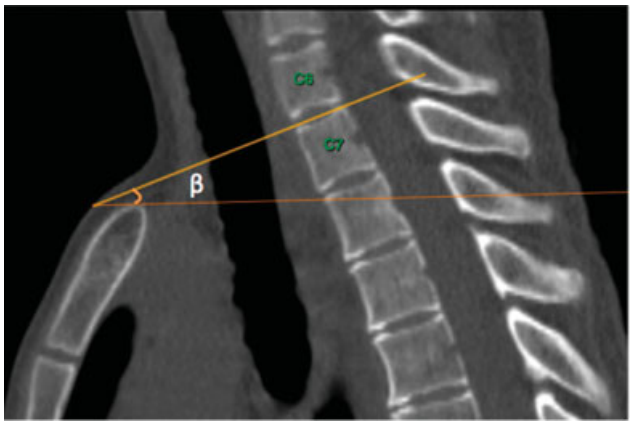

Fig. 4 Intervertebral disc angulation (IDLA).

variance (ANOVA) study were performed to compare the clinical data (age and gender); the Bonferroni posttest was used for further analysis.

The non-parametric IDL and HLS data were converted to ordinal values for statistical purposes. As the C5–6 level was the most cranial level found for IDL in our study, it was given the number 1 designation with subsequent caudal levels being given successive ordinal values. The same method was used for HLS. The most cranial level was C7, and it was given the number 1 designation.

Statistical analysis for HLS and IDL were tested by the Pearson's chi-squared test. All data was analyzed with the statistical software STATA13 (StataCorp., LLC. College Station, Texas, USA). The null hypothesis of no difference was rejected if p-values were < 0.05.

Data from Other Studies

From our literature search, we were able to collect data analogous to our study design from other scientific papers when available. All data was then organized for further comparison with our results.

Results

In total, 300 participants were selected. The mean age was 50 ± 23 years. The male subgroup had a mean age of 49 +/− 18 years (range: 18–91), whereas the female subgroup had a mean age of 51 +/− 23 years (range: 19–92).

The HLS ranged from C7 to T4, with T2 being the most frequent level (34.3%), followed by the T1-2 (20.7%) and T2-3 (17.3%) disc levels. The least common HLS levels were T4 (0.3%) and C7 (1.0%) (►**Figure 5**).

The VBA had a mean of 18 +/− 8.94 (range: 1–54 degrees). The IDLA had a mean of 19 degrees +/− 7.9 (range: 0–49 degrees).

The IDL ranged from C5–6 to T2–3, with C7–T1 being the most frequent level (46%), followed by the T1-T2 (26.7%) and C6-7 (26.7%) levels. The least common IDL levels were T2–T3 (1.7%) and C5–6 (3%) (►**Figure 6**).

When comparing male and female groups, we found statistically significant differences in both IDLA ($p = 0.003$) and VBA ($p = 0.02$), with males having higher values. In terms of age, statistically significant differences were found between all age groups in both IDLA ($p = 0.01$) and VBA ($p = 0.001$), with the older groups having higher values. Further analysis with the Bonferroni posttest revealed statistically significant differences in values between all

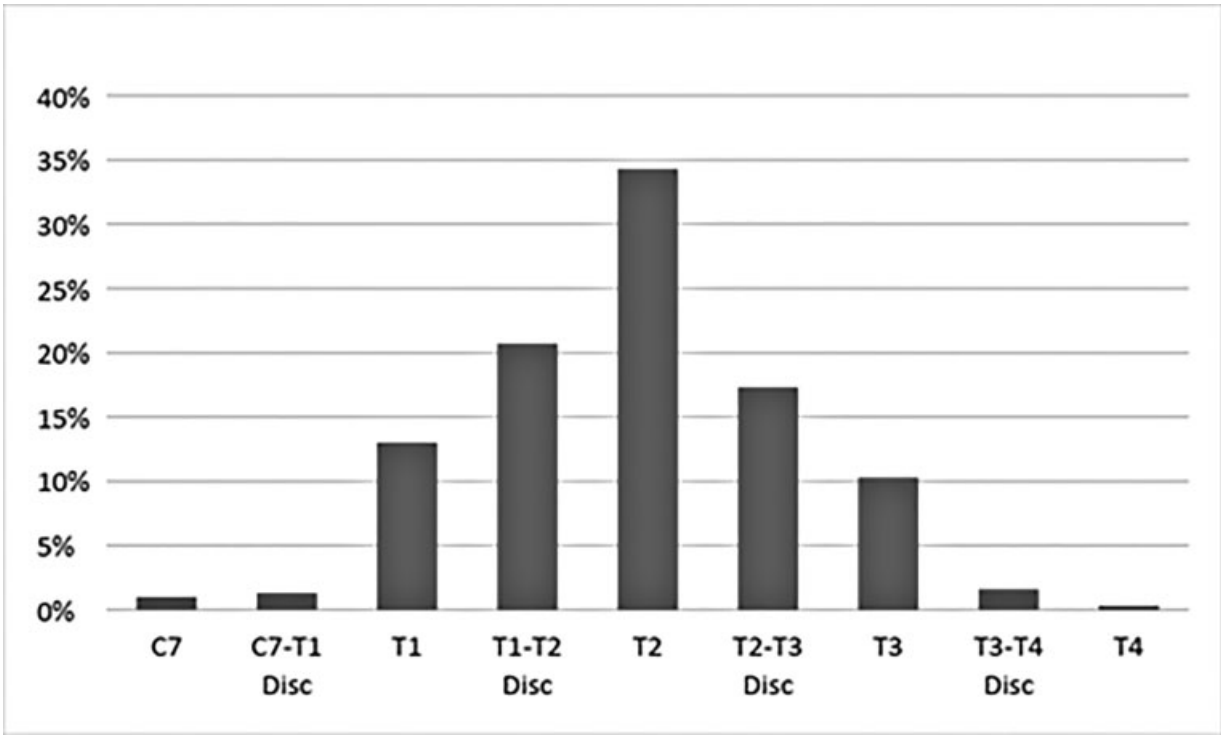

Fig. 5 Horizontal level above the sternum (HLS) distribution per level in the current study.

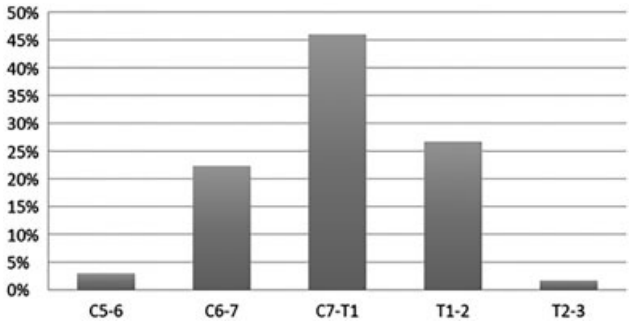

Fig. 6 Intervertebral disk line (IDL) distribution per level in the current study.

Table 2 *P*-value of the intervertebral disc line angulation and vertebral body angulation according to age and gender groups

	Group 1 vs 2	Group 2 vs 3	Group 1 vs 3	Gender
IDLA	0.001	0.01	< 0.001	0.03
VBA	0.005	< 0.001	0.006	0.02

Abbreviations: IDLA, intervertebral disk line angulation; VBA, vertebral body angulation.

Table 3 *P*-value of the intervertebral disc line and horizontal level above the sternum according to gender and age groups

	Age	Gender
HLS	$p = 0.395$	$p = 0.799$
IDL	$p < 0.001$	$p = 0.4$

Abbreviations: HLS, horizontal level above the sternum; IDL, intervertebral disk line.

possible combinations between the 3 age groups for both IDLA and VBA with the p-values shown in ►**Table 2**.

There were no statistically significant differences in HLS between male and female groups ($p = 0.3$) or between the different age groups ($p = 0.79$) (►**Table 3**). There was no difference in IDL between male and female groups ($p = 0.4$). However, there was a difference between the age groups ($p < 0.001$), with the older group intersecting at a more caudal level (►**Table 3**).

The IDL and HLS in our sample demonstrated more cephalad values compared to other previously reported population samples. The results from previously available data for IDL and HLS are shown in ►**Tables 4** and **5** and ►**Figure 7**, showing the references and the values of parameters.

Table 4 Intervertebral disc line distribution in different studies

IDL	Sugino et al.	Sharan et al.	Karikari et al.	Mai et al.
C5–C6	100%	100%	100%	100%
C6–C7	96.6%	99.0%	99.4%	92.7%
C7–T1	74.3%	95.2%	91.7%	85.5%
T1–T2	28.3%	59.4%	82.7%	62.2%
T2–T3	1.6%	14.1%	17.3%	16.1%
T3–T4	0.0%	0.0%	0.0%	0.0%

Abbreviation: IDL, intervertebral disk line.

Discussion

Preoperative planning is a very crucial element to spine surgery. A lack of attention in this step, especially in the cervicothoracic junction, can produce poor outcomes and avoidable complications due to surgical procedure. The decision to perform osteotomy in the anterior cervicothoracic approach will depend on various factors including patient's weight, short neck, obesity, local spine alignment, and extent of the pathology.

In order to address that, Sharan et al.,[14] in 2000, studied a line that would cross tangentially to the suprasternal notch and a line that would divide the intervertebral disc in half in the sagittal plane, named by the researchers as the "lowest intervertebral disc visualized." The authors described that if both lines were caudal to the pathology being treated, then an osteotomy could be avoided.[14]

In 2002, Frazer et al.[3] tested new parameters to help surgeons approach the anterior cervicothoracic junction. However, in our opinion, this method used advanced trigonometry and was far too complex for routine usage.

Karikari et al.,[6] in 2009, used MRI images and clinically tested the same "lowest intervertebral disc visualized" concept used by Sharan et al.[14] to predict when a sternal osteotomy would not be necessary. In the same year, Teng et al.[15] proposed a new cervicothoracic angle. The angle is formed by a horizontal line from the sternal notch and a second line from the sternal notch to the C7–T1 disc space. Depending on where the pathology was located within this angle, it was possible to determine whether an osteotomy was necessary.

Table 5 Horizontal level above the sternum distribution in different studies

	C7	C7–T1	T1	T1–2	T2	T2–3	T3	T3–4	T4
Sharan et al.	0.94%	–	1.89%	–	41.51%	–	49.06%	–	6.60%
Lakishmanam et al.	–	–	3.66%	2.44%	19.51%	31.71%	34.15%	4.88%	3.66%
Teng et al.	–	–	–	–	26.32%	20.00%	42.11%	10.53%	1.05%
Sugino et al.	1.00%	1.33%	13.00%	20.67%	34.33%	17.33%	10.33%	1.67%	0.33%

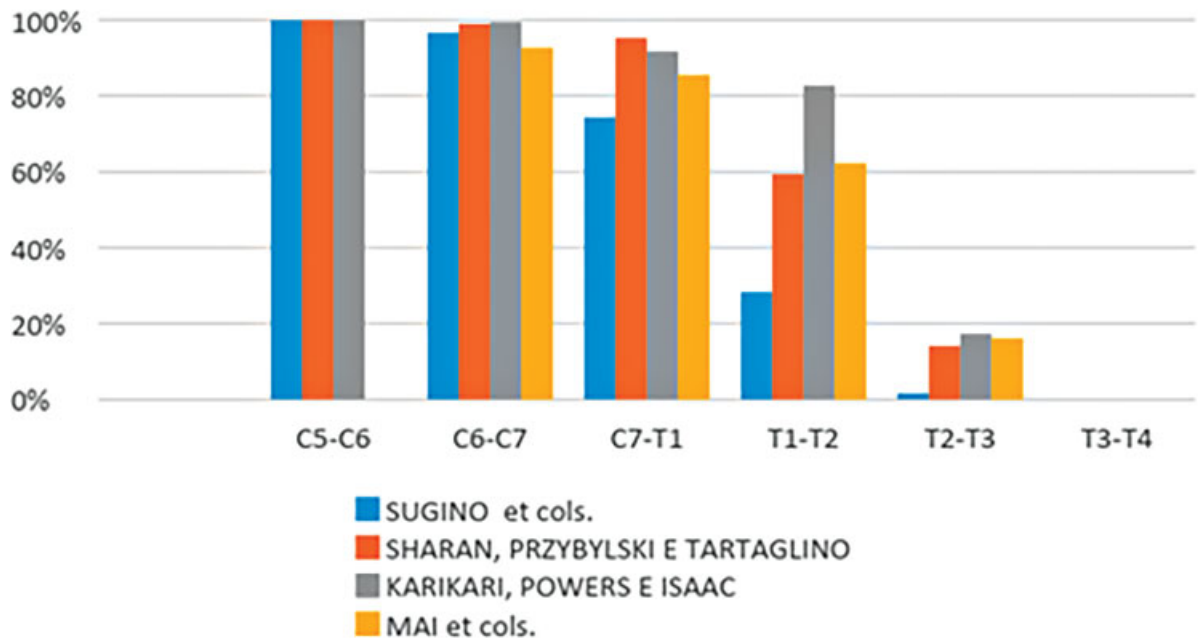

Fig. 7 Intervertebral disk line (IDL) distribution in different studies.

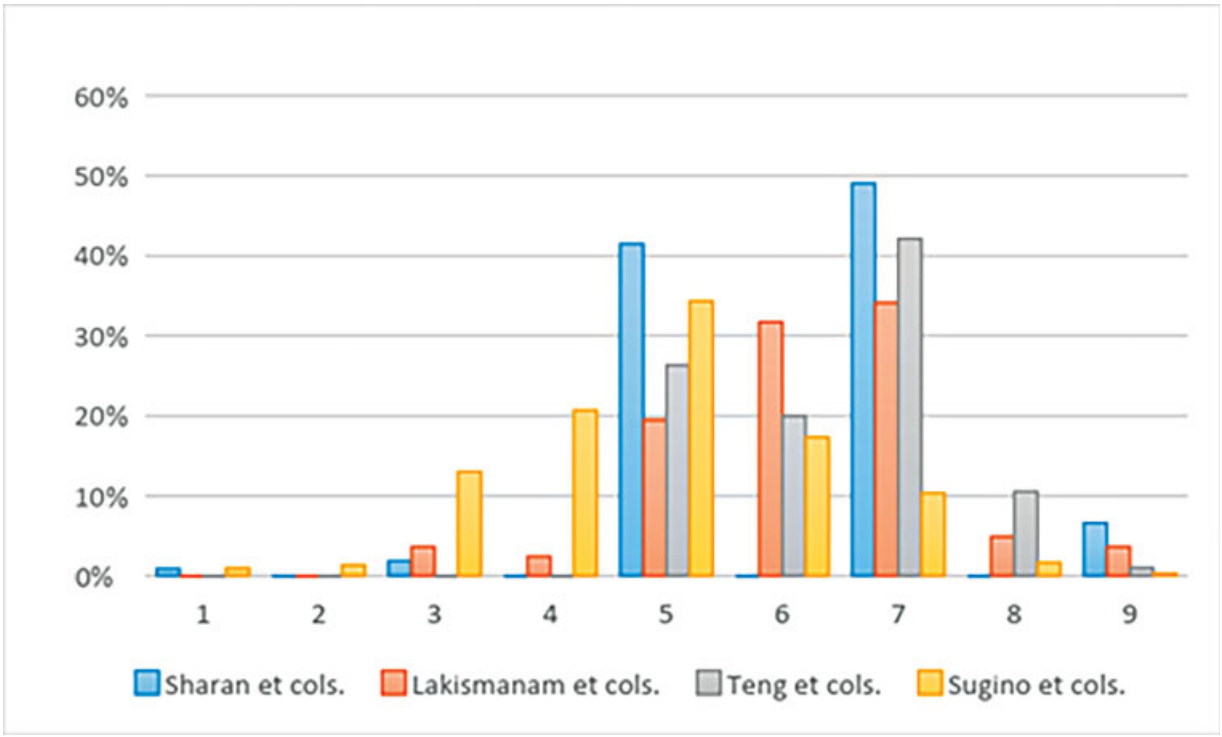

Fig. 8 Horizontal level above the sternum (HLS) distribution in different studies.

In 2011, Falavigna et al.[13] described a "surgeon's line to the disc" in a similar fashion as the one described by Sharan et al.[14] as a preoperative method in the cervicothoracic junction.

These studies tried to develop reliable and simple methods for better surgical planning. We selected the two best methods for our study, those that we believe produce the most reliable, simple, and reproducible techniques in terms of surgical planning. Afterwards, two questions arose: does the Brazilian population have the same anatomy as the populations previously studied and do those parameters undergo any kind of variations within different age or gender groups?

Comparison among Different Populations

After reviewing the literature, three studies which used similar radiographic analysis were used for comparison. The most common level for IDL in our study was T2. This differed from previous studies who reported a more caudal IDL (►**Figure 7**). For example, in our study, T2-3 was the IDL 1.6% of the time, while Sharan et al.[14] reported it as 14.1%, Karikari et al.[6] 17.3% and Mai et al.[16] 16.1%. When considering the level T1–2, our study (28.3%) showed an even higher difference when compared to other populations (respectively 59.4%, 82.7%, and 62.2%) (►**Table 4**).

In terms of HLS, the most common level in our study was T2 (34.33%) followed by T1–T2 (20.67%) and T2–3 (17.33%) (►**Table 5**). By contrast, Lakshmanam et al. (34.15%)[7] and Teng et al. (42.11%)[15] both reported T3 as the most common HLS level, followed by T2–T3 (31.71%) and T2 (19.51%) in the Lakshmanam et al. study, and T2 (26.11%) and T2–T3 (20.0%) in the Teng et al.[15] study (►**Figure 8**).

With these differences, we could once again say that the Brazilian population has less favorable anatomy to treat the cervicothoracic junction, and that this may result in needing to trespass osseous anatomy during the approach. In other words, it would be more difficult to treat anterior pathologies in the Brazilian population.

Levels and Demographic

When comparing results between age or gender groups, the HLS did not show any statistical difference. This measurement could also represent indirect vertical translation of the spine in relation to the sternum. With aging, there is a normal increase in thoracic kyphosis, which could alter the HLS. However, in our study, we did not see any translational differences with aging.

When comparing the gender and age groups, the VBA and IDLA had similar behavior. This finding could be explained because, trigonometrically they represent the same measurement in adjacent levels, which normally have smooth transitions between levels. Both angular values were higher in males and older age groups. Our understanding is that these findings were due to normal kyphotic changes secondary to aging, where the upper thoracic levels rotate, increasing the angular rotation.[17]

When analyzing IDL, no difference was found between gender groups. However, we did find that with age, it may be harder to access spinal levels in the cervicothoracic junction because of the cranial migration of the disc line crossing above the sternal notch. This is a consequence of vertebral rotation rather than vertical translation occurring with aging. We would also say that in addition to older age, our specific geographic population is more exposed to the risk of a sternal osteotomy in each anterior approach for the cervicothoracic junction. This fact is an anatomical observation that occurs in the Brazilian population. The increase in T1 slope, indirectly measured by the disc angulation, also plays a role. Further investigation is needed to confirm this correlation in different populations. This phenomenon is common in older patients as our study and previous literature demonstrate. The method we used for surgical planning is simple and reliable. Even if the operative level is not above the sternum, a corpectomy can be utilized in the vertebral body above the desired level to perform the surgery, although this increases surgical morbidity and changes the surgical planning entirely.

As a retrospective observational study, it has some limitations. We could not test our hypothesis prospectively, nor test the clinical significance of our study. Other studies have previously investigated the accessibility of the cervicothoracic junction via CT scan. However, no study has analyzed the data comparing different age and gender groups. More data from different populations would be necessary to have a better understanding of our findings, but this data does not exist in the literature.

Conclusion

Compared to other populations, our sample had more cases of cephalad IDL and HLS, indicating that less levels could be approached anteriorly without the need for a sternotomy. When comparing gender groups, there was no difference for IDL and HLS, whereas VBA and IDLA tended to be higher in males. HLS was similar amongst the age groups, suggesting that there was no vertical translation between the sternum and spine. Higher angles for VBA and IDLA were shown for older groups when compared to younger ones. IDL showed more caudal levels in older patients due to vertebral rotation rather than a translational difference.

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Conflict of Interests
Potential Conflicts of Interest: (R. L. S.) nothing to disclose; (A. S. I.) nothing to disclose; (S. C.) Globus consulting, ongoing, and Zimmer Biomet consulting, ongoing; (D. C.) nothing to declare; (L. M.) nothing to disclose; (C. F. P. S. H.) nothing to disclose

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