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CORRELATION BETWEEN THE TUFFIER'S LINE AND THE SPINOPELVIC PARAMETERS

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Abstract: Tuffier's line (TL) is a horizontal line that connects the two superior iliac crests and is used to determine L4 and L5 vertebrae levels. Spinopelvic parameters have been gaining further importance in the diagnosis and treatment planning of spinal diseases. This study aims to reveal whether there is an interaction between TL and spinopelvic parameters. We examined the 113 patients who consulted our clinic for low back pains. TL levels were divided into five categories as L4 body, L4 inferior endplate, L4-5 disc space, L5 superior endplate, and L5 body. In the study group, 70 of the cases (61.9%) were female, 43 (38.1%) were male, and the average age was 50.8 (21–77). TL was determined to pass through L4 body in 38.9% of cases (n=44) regardless of gender. It was observed that sacral slope (SS) and lumbar lordosis (LL) were affected by the changes in TL level (P<0.05), whereas PI, PT and SVA were not affected (P>0.05). SS and LL being affected by changes in TL levels indicates that TL should be assessed together with the spinopelvic parameters. To conclude, TL is a potential spinal parameter that should be included in the spinopelvic parameters.

Keywords: Tuffier's line, Spinopelvic parameters, Spine surgery

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1. Introduction

Pelvis is considered integral to the spinal column. Its positioning in the sagittal and coronal planes, helps humans stand up straight on two feet and contributes to the mechanics of walking (Merrill et al., 2018; Zhang et al., 2020). In addition, the correspondence of pelvis and spine is also known to be required for minimized energy to stand up straight (Hasegawa and Dubousset, 2022). Dubousset suggested pelvis to be a caudal vertebra of the spinal column. Legaye et al. (1998) mentioned that Duval-Beaupere et al. examined the positioning of pelvis to the spine for global balance and included pelvic incidence (PI) to spinal parameters. Roussouly and Pinheiro-Franco (2011), reported different spine structures in individuals and noted the importance of alignment between the pelvis and the vertebral column, defining four different positioning of pelvis to the vertebral column. The degenerative processes spinopelvic parameters and affecting the lumbar area are concluded to trigger kyphotic deformity, persistent back pains, neural losses, and reduced quality of life (Zhang et al., 2020). The application of spinopelvic parameters in the surgical treatment of adult spinal deformity has increased over the recent years (Schwab et al., 2013). It has also been proved that measurement data of spinopelvic parameters contributed substantially to post-surgical patient satisfaction (Noshchenko et al., 2017; le Huec et al., 2019).

Tuffier's line (TL) was first used by French surgeon Tuffier in 1900 to determine the point of entry in lumbar subarachnoid injections and was described as the horizontal line separating the two superior iliac crests of the pelvis (Tuffier, 1920). Also known as the "intercristal line", this imaginary line usually crosses through the fourth lumbar vertebra body or through L4-5 disc space (Cooperstein and Truong, 2017). Nowadays, TL is widely used by neurosurgeons, anesthesiologists, orthopedists, neurologists and physiotherapists in diagnosis and treatment. However, literature review concludes no studies on the possible effects of changes in spinopelvic parameters on the TL level.

In this study, we aimed to show the relationship between TL and spinopelvic parameters and to reveal whether it will be a candidate for spinopelvic parameters to be used in the planning of spinal surgeries in the future.

2. Materials and Methods

This study was carried out in compliance with the principles of the Declaration of Helsinki upon the approval dated February 10, 2021 and numbered 2020-02 of the Clinical Research Board of Ethics of the Faculty of Medicine. We included patients who applied between 2017 and 2021 to the Neurosurgery clinic for low back pains. Measurements were carried out retrospectively on standing scoliosis imaging. The spinopelvis angles were measured on the bilateral scoliosis images including the area between the skull and the femoral neck. The study also included the radiographic images of 113 patients in

compatible format and sufficient resolution for standard parameter measurement. Patients suffering from vertebral compression fracture, sacralization, lumbalization, de novo or congenital scoliosis, lumbar spondylolisthesis, lower limb asymmetry, or congenital hip dislocation, or whose radiographic images are not suitably formatted for the study were excluded. We included cases between the ages 20 and 80 without previous spinopelvic or hip pathologies. Measurements were carried out on the free software Surgimap (Surgimap; Nemaris, New York, 133 USA) by an experienced spine surgeon. Previously standardized PI, pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL) and sagittal vertical axis (SVA) parameters were used in the measurement of spinopelvic parameters (Roussouly and Pinheiro-Franco, 2011; Lafage et al., 2015; le Huec et al., 2019). Images showing the first cervical vertebra, femoral head and sacrum were uploaded on the Surgimap software prior to the measurement of spinopelvic parameters. The measurement of parameters was carried out in compliance with the Surgimap user guide (Surgimap®, 2008). TL level was determined and categorized as described in the literature by drawing a horizontal line between the two superior iliac crests on the antero-posterior view of lumbosacral area (Kim et al., 2003; Snider et al., 2008; Horsanalı et al., 2015). TL levels were divided into five categories as L4 body, L4 inferior endplate, L4-5 disc space, L5 superior endplate, and L5 body based on their projection on the spinal plane.

2.1. Statistical Analysis

Demographic data of the cases were analyzed as distribution by age and gender. Cross-tabulation test was applied to determine the distribution of TL levels by gender. Kolmogorov-Smirnov normality test concluded normal distribution of data. Independent sample t-test was conducted to compare the distribution of spinopelvic parameters by gender. One-way ANOVA analysis was applied to compare pelvic parameter distribution by age groups. Bonferroni post hoc (comparison of multiples) test was conducted to determine the differences between the groups. Kruskal-Wallis test was applied to determine the distribution of spinopelvic parameters and statistical meaning by TL. Dunn's test of multiple comparisons (post hoc) was conducted to determine any significant difference between groups. The correlation between TL and spinopelvic parameters was analyzed by Dunn's test of multiple comparisons. Cases where the "P" value is lower than 0.05 were considered statistically significant.

3. Results

Of the cases included in the study, 70 (61.9%) were female and 43 (38.1%) were male. Cases were categorized in three groups by age (Figure 1).

TL was determined to pass through L4 body in 38.9% of cases (n=44) regardless of gender. While TL levels varied between male and female, the differences weren't statistically significant (P>0.05). TL passes through L4 body in 51.2% (n=22) of male. In female, its clusters in two planes and passes through L4 body in 31.4% (n=22) and through L5 superior endplate in 34.3% (n=24) (Table 1).

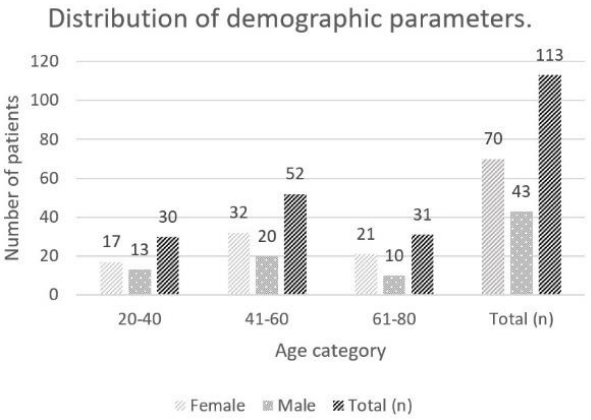

Figure 1. Distribution of demographic parameters.

PI and PT were observed to be higher in female than in male (P<0.05). SS and LL, as well as SVA distance were all higher in female, was not statistically significant (P>0.05), (Table 2).

When compared by age groups, a statistically significant difference was determined between the PT and SVA measurements (Bonferroni's comparison of multiples, P<0.05) though the PI, SS and LL measurements lacked any such difference (P>0.05). It was thus concluded that the PT angle increased by age. In cases aged 20 to 40 years, PT was also observed to decrease. There was no statistically significant difference between the changes in TL levels according to age (Bonferoni's was applied in the ANOVA, P>0.05, P=0.46) (Table 3).

Table 1. Distribution of Tuffier's line by gender

Tuffier's line level	Female (n=70)	Male (n=43)	Total (n=113)
L4 body	22 (31.4%)	22 (51.2%)	44 (38.9%)
L4 inferior endplate	9 (12.9%)	8 (18.6%)	17 (15.0%)
L4-5 disc space	24 (34.3%)	7 (16.3%)	31 (27.4%)
L5 superior endplate	10 (14.3%)	5 (11.6%)	15 (13.3%)
L5 body	5 (7.1%)	1 (2.3%)	6 (5.3%)

Distribution of vertebrae level where TL passes through in male and female and comparison by cross-tabulation test. No difference determined between the groups (P>0.05).

Table 2. Difference between spinopelvic parameters by gender

	Female	Male	P
PI (°)	56.0±10.9	50.4±9.7	0.007*
PT (°)	17.6±9.8	13.8±8.4	0.039*
SS (°)	38.5±7.7	36.6±6.3	0.174
LL (°)	56.2±14.2	53.1±13.5	0.254
SVA (mm)	9.2±44.0	-5.7±35.7	0.063

Data is provided as average and standard deviation. The p values marked with "*" are considered to be statistically significant (P<0.05).

Table 3. Average age groups for TL levels

Tuffier's line level	n	Age (mean)
L4 body	44	52.5
L4 inferior endplate	17	46.1
L4-5 disc space	31	52.2
L5 superior endplate	15	47.7
L5 body	6	53
Total	113	50.8

There was a similar change in SVA with PT; it was observed that SVA progressed in the positive direction with age. Although it was not statistically significant, it was observed that LL decreased with increasing age (P>0.05) (Table 4).

Dunn's multiple comparisons test concluded that SS and LL are affected by different TL levels, while PI, PT, and SVA remained immune to differences in TL levels. SS angle was observed to decline when TL was moved from L4 inferior endplate level towards cranial or caudal levels. The SS angle measured an average of 42.5 degrees as TL passed through the L4 lower endplate and decreased to an average of 35.4 degrees when TL moved into the L4-5 disc space. This change was also found to be statistically significant (P<0.05) (Table 5).

A similar correlation to that between SS and TL levels was observed in LL. LL angle was observed to decline when TL was moved from L4 inferior endplate level towards cranial or caudal levels. LL was larger when TL passed through L4 inferior endplate than when it passed through L4 body, L4-5 disc space or L5 superior endplate levels with a statistically significant difference (P<0.05). LL tended to increase again when TL passed through L5 body, but this increase was not statistically significant (P>0.05) (Table 5). There were no statistically significant changes in the average PI, PT or SVA measurements by TL levels either.

Table 4. Average and standard deviation (mean±sd) values of spinopelvic parameter measurements per age group

Age categories	20-40 n=30	41-60 n=52	61-80 n=31	Average	P
PI (°)	50.4±10.4	53.9±9.7	57.2±12.1	53.9±10.8	0.05
PT (°)	12.6±9.2	15.5±8.4	20.7±9.8	16.2±9.5	0.003*
SS (°)	37.9±5.9	38.5±7.9	36.5±7.3	37.8±7.2	0.49
LL (°)	55.5±12.9	55.0±14.3	54.8±14.7	55.1±13.9	0.976
SVA (mm)	-10.7±36.9	1.6±38.0	20.4±46.6	3.503±41.5	0.012*

Data is provided in standard and average deviation (mean±sd). *There is a statistically significant difference in pelvic parameter measurements by age group (P<0.05).

Table 5. Distribution of spinopelvic parameters by TL levels

	Tuffier's line level					
	L4 body	L4 inferior endplate	L4-5 disc space	L5 superior endplate	L5 body	P
PI (°)	53.8±8.9	55.4±10.5	52.5±10.2	55.1±17.6	54.8±7.5	0.903
PT (°)	16.2±9.2	12.9±9.4	17.1±7.3	17.6±13.9	16.2±0.3	0.619
SS (°)	37.6±7.4$^{\alpha}$	42.5±7.2$^{*\alpha}$	35.4±6.6*	37.6±6	38.6±7.5	0.027
LL (°)	54.5±14.8$^{\gamma}$	63.5±13.5 $^{\alpha\beta\gamma}$	52.8±12.9$^{\beta}$	49.1±11.5$^{*\alpha}$	62.1±8.9*	0.020
SVA (mm)	3±34.2	-15.3±35	5.4±39.7	21.2±46.1	6.6±84	0.117

Measurements are provided as standard "±" average deviation. There are statistically significant differences between the spinopelvic at TL levels marked with the "α, β, γ or *" superscripts, (P<0.05).

4. Discussion

This study aims to evaluate the correlation between the TL level and spinopelvic parameters and determined that while SS and LL were indeed affected by the different TL levels, PI, PT and SVA remained immune to these differences. Also, observed that TL often passes through L4 body in male, and through L4 body and L5 superior endplate in female. However, were no significant differences between the TL levels in male and female. While the SVA shifted towards the positive side with age, there was an increase in the PT angles.

TL is an anatomical indicator separating the two superior iliac crests, used to determine the L4-5 disc space. It is, therefore, widely used by clinicians in the diagnosis and treatment of lumbar area diseases. It was noted that there were many research on TL, mostly focused on changes by geographic regions, demographics and anatomical differences (Kim et al., 2003; Horsanalı et al., 2015). The research by Snider et al., for instance, affirmed that TL passes through L5 superior endplate in female and through L4 body in male (Snider et al., 2008). Chowdhury et al., however, determined no differences between genders and concluded that TL passes through L4 body by 43.3% (Chowdhury and Sharma, 2018). The same research also reported no substantial correlation between the TL level and age. Literature includes articles suggesting TL levels changing by gender (Snider et al., 2008), as well articles claiming otherwise (Chowdhury and Sharma, 2018). The average age in our study was 50.8, and there was no significant correlation between the TL levels and the average age of cases. TL levels were observed not to be affected by gender either. TL passes through L4 body in 39% of cases regardless of gender. In male, TL passes through L4 body in 51%. In female, it passes through L4-5 disc space in 34% and through L4 body in 31%percent.

The importance of global balance and spinopelvic parameters in spine surgery have already increased and continues to increase (Schwab et al., 2013; Malçok, 2021). Patients suffering from disrupted spinopelvic parameters have difficulties leading a healthy and quality of life (Schwab et al., 2013). Including spinopelvic parameters in the treatment planning was reported to contribute positively to the prognosis of spinal pathologies (le Huec et al., 2019). It is widely used particularly in the degenerative scoliosis surgery (Roussouly and Pinheiro-Franco, 2011; le Huec et al., 2019). More comprehensive research on spinal biomechanics adds new parameters to the existing ones 19. However, literature review concludes that are no previous studies on the inclusion of TL in the measuring of spinopelvic parameters. Therefore, it remains unknown whether TL is affected by the spinopelvic parameters.

A study on a large series of adults including 1461 volunteers found that LL, PT and PI were larger in female (Asai et al., 2017). Our study focused on the correlation that had not been studied in detail before, between the position of the SVA, and the LL, PI, SS and PT, and different TL levels. We determined that PI and PT changed by gender and that these angles were significantly higher in female than in male. On the other hand, SS, LL and SVA parameters in female was higher, though not statistically significant. In addition, PT angle and SVA distance increased significantly with age, whereas LL and SS angles decreased.

Today, it is acknowledged that pelvis should be included in the spinal anatomy in deformity correction surgery planning (Vila-Casademunt et al., 2015). It is also suggested to include the correlation between the position of the pelvis and the lumbar vertebral column in understanding the biomechanical issues caused by spinal pathologies (Roussouly and Pinheiro-Franco, 2011). As all changes in the pelvic position, will alter the positioning of the pelvis compared to the lumbar spine, it is the expected outcome that the TL level should be affected by these changes. TL level is considered to be an indicator of the lumbar spine and pelvis correlation (Vila-Casademunt et al., 2015).

With the exception of pathological incidences that affect the pelvic anatomy, PI is known not to change in the adulthood (Legaye et al., 1998). However, LL, PT and SS do change based on the position of the pelvis (Asai et al., 2017). We also studied the correlation between different TL levels and the spinopelvic parameters. We observed that TL passes through L4 inferior endplate when the SS is the largest, and through L4-5 disc space when the SS angle is the smallest. As a result, the movement of TL level towards cranial or caudal area from the L4 inferior endplate level results in the narrowing of the SS angle. We also determined that the largest LL occures, as in SS, when TL level passes through L4 inferior endplate. When TL level moves towards cranial or caudal area from L4 inferior endplate, as in SS, LL declines. When TL moves towards L5 body, both SS and LL increases. In that case, when TL is at the L5 body level, it indicates that pelvis is tilted towards the front. This change also explains the increase in the SS angle when TL passes through L5 body level. The decline in the SS and LL are known to result in disruptions in the spinopelvic parameters. Described as flat back syndrome, this is among the main causes of backpains and disc degenerations (Zhang et al., 2020). Furthermore, our findings showed no significant association between different TL levels and changes in PI, PT, and SVA.

5. Conclusion

Our study concluded that, TL mainly passes through L4 body level, followed by L4-5 disc space regardless of gender. A significant correlation was determined between the spinopelvic parameters SS and LL and different TL levels. As a result of this study, it was seen that TL passed mainly from L4 body level, then L4-5 disc space, regardless of gender. In addition, we concluded that there is a significant relationship between the change in SS and LL angles and TL levels. The TL reached

the greatest SS and LL angles when the L4 was at the level of the lower endplate, while it tended to decrease when the TL moved cranially or caudally. It is concluded that, SS and LL are affected by different TL levels, while PI, PT and SVA remained immune to differences in TL levels. Our results support the idea that including TL in spinopelvic parameters will help to better understand the relationship between spine and pelvis.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	A.A.	Ü.A.M.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Approval/Informed Consent

This study was carried out in compliance with the principles of the Declaration of Helsinki upon the approval of the Clinical Research Board of Ethics of the Faculty of Medicine (approval date: February 10, 2021 and protocol code: 2020-02/29).

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