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Variability in the projection level of the vertebra prominens: a cadaveric study

Trifon Totlis[1], Andreas Sammer[2,3], Maria Piagkou[4], Konstantinos Natsis[1], Panagiotis-Konstantinos Emfietzis[1], Filippos Karageorgos[1], George Tsakotos[4], George Triantafyllou[4], Georg Feigl[5,6]

[1]Department of Anatomy and Surgical Anatomy, School of Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece, [2]Österreichische Arbeitsgemeinschaft für Manuelle Medizin, Graz, [3]Ordination Dr. Sammer, Raaba/Grambach, Austria, [4]Department of Anatomy, School of Medicine, Faculty of Health Sciences, National and Kapodistrian University of Athens, Athens, Greece, [5]Institute for Anatomy and Clinical Morphology, Witten/Herdecke University, Witten, Germany, [6]Institute of Clinical Morphology, Medical University of Graz, Graz, Austria

Abstract: The 7th cervical vertebra (C7) is described as having the most prominent spinous process (SP) and is characterized as the "vertebra prominens" (VP) of the cervical spine in anatomy textbooks. The VP is an important anatomical landmark of the neck for clinical examination and therapeutic intervention. The present study identifies the level of the most prominent SP of the cervical and uppermost thoracic vertebrae in a cadaveric cohort. Thirty-nine (23 female and 16 male) cadavers of a mean age of 77.5 years were investigated in a prone position and a certain cervical kyphotic bending. The most prominent SP, at the base of the neck, was palpated and marked with a wedging nail into the SP of the vertebra. The cervical region was dissected, and a blind investigator examined whether the nail was placed into the SP of C7 or the SP of another upper or lower vertebra. In 19 out of 39 cadavers (48.7%), the C7 was identified as the VP (typical anatomy), followed by the C6 (in 14 cadavers, 35.9%), C5 (in 4 cadavers, 10.3%). In 2 cadavers (5.1%) the first thoracic vertebra was identified as having the most prominent SP. Although C7 is described as the VP, in the present study the SP of C7 was the most prominent in less than 50%. The high variable projection level of the most prominent SP of the cervical vertebra holds great clinical significance for spine examination, neck surgery, and spinal anesthesia.

Key words: Spine, Anatomy, Vertebra, Cadaver, Palpation

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Introduction

The seventh cervical vertebra (C7) is characterized as the "vertebra prominens" (VP) due to its most elongated spinous process (SP), which can be recognizable towards the lower point of the nuchal furrow [1, 2]. The ligamentum nuchae and muscles, such as the trapezius, the spinalis capitis, the semispinalis thoracis, the multifidus, and the interspinales attach to the prominent tubercle of the C7 SP [1]. The VP is one of the most important surface landmarks of the neck due to its clinical significance (clinicodiagnostic examinations, therapeutic interventions, and neck surgeries) [3]. Palpation is frequently used in clinical practice to locate the VP. Anesthesiologists use the C7 SP to determine the level of epidural catheters' insertion, whilst the C7- the first thoracic vertebra (T1) level is used for cervical interlaminar epidural steroid injections [4]. The morphology of the C7 SP is often used in posterior surgery of the lower cervical region [3]. However, sporadically, the C6 SP may be the most prominent, and quite rarely, the T1 SP [2, 5]. Previous investigations have mostly relied on imaging devices like computed tomography scans or radiography to determine the VP level. However,

Corresponding author:
Trifon Totlis
Department of Anatomy and Surgical Anatomy, School of Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece
E-mail: totlis@auth.gr

it is worth considering how accurately the VP can be determined through palpation alone, which is a technique commonly used in physiotherapy [6] and manual medicine [7]. In addition, it might be important to point out possible problems, which might help to reduce injections at false vertebral levels with consecutive "failure". Drerup and Hierholzer [8] pointed out that the definition of the "most prominent" bony part should be rejected, by using surface measurement techniques of stereophotography or raster-stereography.

The current study aims to assess the level of the VP, as the "most prominent bony part" of the base of the neck in a cadaveric cohort using exclusively palpation, and to evaluate, how frequently the C7 SP does not correspond to this definition.

Material and Methods

The study was carried out on 40 cadaveric bodies donated to Anatomical Science all formalin embalmed with Thiel's method [9, 10]. Thiel's method is most suitable for such investigations due to its softness [11-13] with consecutive easy palpability of bony landmarks [14]. The bodies were donated before death after signed informed consent and were investigated under the approval and the strict rules of the Anatomical Donation Program of the Medical University of Graz and according to Austrian burial law. All procedures performed adhered to the ethical standards outlined by the Institutional Authorities and no Institutional Review Board approval was required for this kind of study. After the exclusion of donated bodies due to a lack of demographic data, the study's sample consisted of 39 (16 male and 23 female) cadavers of a mean age of 77.5 years (range 31–99). Dissection data were collected in the Macroscopic and Clinical Anatomy Department of the Medical University of Graz, during the years 2010 and 2011. The mean height and weight of the cadavers were 167.8 cm (range 152–183) and 66.3 kg (range 48–105).

Landmarks identification method

The investigation took place on donated bodies in a prone position on the anatomy table with a roller placed under the upper chest to achieve cervical kyphosis for the VP's better identification. The procedure was performed before the dissection of the back, so the bodies were not turned around anymore to reduce the risk of the inserted nail displacement. A single investigator with more than 20 years of experience with Thiel's embalming method identified the most prominent bony landmark, namely the SP, by inspection and palpation from a lateral view at the base of the neck. After the determination of this landmark, the investigator incised the skin, exposed the determined bone, and forcedly inserted a nail with a hammer into the SP of the exposed bony landmark to ensure and avoid displacement. The method described above is similar to the one that is applied to assess Tuffier's or Jacoby's line concerning the L4 SP [14]. Afterward, the cervical region was dissected, and a blind investigator examined whether the placing nail was into the C7 or another cervical or thoracic vertebra (Fig. 1). Skin, subcutaneous fat tissue, and muscular layers were removed, and the vertebral arches and processes were exposed. The full spine overview ensured a precise evaluation. In case of any doubts about the nail's displacement, the bodies were excluded. The data collection and assessment were performed during the dissection course for medical students.

Statistical analysis

Statistical analysis was performed to demonstrate any discrepancies in the VP distribution, despite the limited statistical power due to the small sample size. IBM SPSS Statistics for MacOS, version 29 (IBM Co.) was used for the statistical analysis. The following tests were applied: chi-square and McNemar test to compare nominal data- differences between vertebral prominens and sex. A *P*-value less than 0.05 was considered significant, while the results are presented as mean and standard deviation unless otherwise stated.

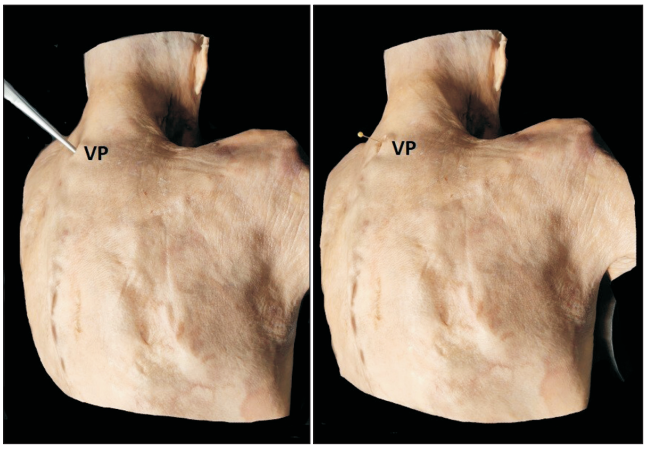

Fig. 1. The most prominent spinous process (vertebra prominens, VP) identified at the base of the cervical area in an embalmed donated cadaver, under the adequate position.

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Table 1. Vertebra prominens distribution by vertebral level and sex

Vertebral level	Female	Male	Total sample
C5	3 (13.0)	1 (6.3)	4 (10.3)
C6	10 (43.5)	4 (25.0)	14 (35.9)
C7	8 (34.8)	11 (68.8)	19 (48.7)
T1	2 (8.7)	0 (0)	2 (5.1)
Total	23 (100)	16 (100)	39 (100)

Values are presented as number (%). C5, fifth cervical vertebra; C6, sixth cervical vertebra; C7, seventh cervical vertebra; T1, first thoracic vertebra.

Table 2. Sex dimorphism for different vertebrae prominens

Sex	C5	C6	C7	T1
Male	1	4	11	0
Female	3	10	8	2
P-value	0.455	0.191	0.025*	0.212

C5, fifth cervical vertebra; C6, sixth cervical vertebra; C7, seventh cervical vertebra; T1, first thoracic vertebra. *A *P*-value<0.05 was considered significant.

Ethical approval

All procedures performed adhered to the ethical standards outlined by the institutional Scientific Committee (IRB) and complied with the principles of the 1975 Helsinki Declaration and its later amendments. No IRB approval is required for this kind of study.

Results

In 19 out of 39 cadavers (48.7%), the VP was the C7 (typical anatomy), followed by the C6 in 14 cadavers (35.9%), by the C5 in 4 cadavers (10.3%), and by T1 in 2 cadavers (5.1%). The sex distribution regarding the VP levels is summarized in Table 1. In males, the most frequent VP was the C7 (68.75%), followed by the C6 (25%), and the C5 (6.25%). No VP was found at the level of T1 in males. In females, the most frequent VP was the C6 (43.5%), followed by the C7 (34.8%), the C5 (13%), and the T1 (8.7%). The sex dimorphism for the VP is summarized in Table 2. The analysis revealed that only the C7 vertebrae presented sex dimorphism in their SPs (P=0.025), with males presenting a higher frequency of projection. The sex impact was not significant for the C5, C6, and T1 vertebrae. Statistical analysis revealed that C7 and C6 significantly appeared more frequently as VP compared to C5 (P=0.002 and P=0.031, respectively) and T1 (P<0.001 and P=0.004, respectively). However, the difference between C6 and C7 was not significant (P=0.392) (Table 3).

Table 3. Differences between different vertebrae prominens

Prominens vertebra	C5	C6	C7	T1
C5	-	0.031*	0.002*	0.687
C6	-	-	0.392	0.004*
C7	-	-	-	<0.001*
T1	-	-	-	-

C5, fifth cervical vertebra; C6, sixth cervical vertebra; C7, seventh cervical vertebra; T1, first thoracic vertebra. *A *P*-value<0.05 was considered significant.

Discussion

The current study identified a high prevalence of variability in the VP spinal projection level. The most common VP was the C7 (48.7%, typical anatomy). Stonelake et al. [2] and Grivas et al. [15] identified the typical VP spinal projection level in the C7 with the highest incidences (73.4%) and (67.82%) respectively.

In the current study, variability in the VP spinal projection level was identified at 51.3%. The most frequent variant of the VP spinal projection level was located at the C6 (35.9%), followed by C5 (10.3%), and T1 (5.1%). Regarding the VP spinal projection level in T1, Stonelake et al. [2] and Grivas et al. [15] reported relative incidences of 14.1% and 32.18%, which are significantly higher than the incidence of the current study (5.1%). Stonelake et al. [2] reported the C6 as the VP at 10.9%, an incidence quite lower than the corresponding of the current study (35.9%). A unique finding of the current study is the C5 level of the VP spinal projection in 4 of 39 cadavers (10.2%), which was not observed in Stonelake et al. [2] and Grivas et al. [15] studies. The differences between the present study and those of Stonelake et al. [2] and Grivas et al. [15] can be explained by the different methodology of investigation, as both studies [2, 15] utilized X-ray radiographs to determine the level of VP spinal projection, while the current is exclusively based on cadavers' dissection in the cervical and upper thoracic area and the use of a nail to mark the VP. The findings of the present study, as well as those of Stonelake et al. [2], were initially based on the VP palpation in the cervical region. In contrast, Grivas et al. [15] relied solely on imaging methods to support their results. As palpation is used by clinicians to perform epidural catheterization or infiltrations to either zygapophysial joints or ligaments, the results should be taken into consideration. Performing such techniques, the risk of a false determination is always possible, as palpation is not as simple as assumed in determining the VP correctly. The current cadaveric cohort

study assessed the VP, taking the "most prominent" osseous landmark in flexion by palpation (Fig. 2).

The sex impact on the variability of the projection level of VP

Typical VP (C7)

According to the current findings, males had a higher incidence (68.75%) of C7 as VP than females (34.8%). These findings are consistent with the results of Grivas et al. [15] study which reported a higher incidence for males (77.78%) compared to females (59.73%), and contrariwise to Stonelake et al. [2], who recorded a higher incidence of VP spinal projection level in C7 for females (78.7%) compared to males (58.8%).

Variable spinal projection levels of VP

A distinct finding in the present study is the identification of C5 as a VP, with a higher incidence in females (13%) than in males (6.25%). Regarding the C6, it was identified as the VP in females (43.5%) compared to males (25%). Stonelake et al. [2] agreed with the current findings, as in their sample, females had a higher incidence of C6 as VP (12.8%) compared to males (6.4%). Regarding the VP spinal projection at the T1 level, according to the current findings, only female spines were identified (8.7%). Stonelake et al. [2] reported that males had a higher incidence (35.3%) of T1 as VP compared to females (6.4%), a contradictory finding to Grivas et al. [15], who reported a higher incidence of VP spinal projection level in T1 in females (40.27%) compared to males (22.22%).

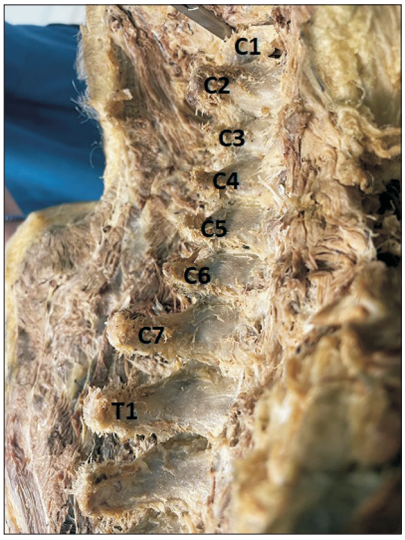

Fig. 2. Dissected area and the identification of the level of the most prominent spinous process at the base of the neck. In this case, the first thoracic vertebra (T1) spinous process appears as the most prominent one. Cn, nth cervical vertebra.

The clinical impact of the study

The palpation and identification of osseous landmarks highly depend on subjective interpretation. Especially, the issue of subjectivity is important for any techniques that use palpation alone, such as infiltration techniques in neural therapy [16]. In anesthesiologic techniques, the description of the determination of the epidural block level lacks precision, as it is generally reported that it should be performed at the C6/C7 or C7/T1 level. Thoracic epidural administration of local anesthetics is highly effective in providing anesthesia and analgesia for thoracic and abdominal surgeries [17]. To ensure optimal anesthesia and minimize complications and side effects, is crucial to accurately identify the vertebral level of the SP projection. In the cervicothoracic spine, two commonly used surface anatomical landmarks are: 1. a line connecting the lowermost point of the scapula, which corresponds to the SP of the 7th thoracic vertebra (T7), and 2. the SP of the VP (usually C7) [18]. The C7 SP is also considered an essential palpable structure, useful for the clinical examination of the cervical and upper back region [1]. The anatomical features of the C7 SP significantly influence the surgical decision of the treatment options. In posterior cervical surgery that targets the lower cervical region, surgeons frequently rely on the specific shape and structure of the C7 SP [3]. The high variability of the level of projection of the most prominent SP encountered in the present study should be taken into consideration by physicians for all the abovementioned reasons.

A simple technique to identify C7 is taught in courses for Manual Medicine. This functional examination is performed on the sitting patient with a flexed cervical spine, the examiner is standing 90° left to him. The examiner touches the SP of the VP with his/her ring finger, correspondently C6 with his/her middle finger and C5 with the index finger of his/her right hand. With the left hand, the examiner touches gently the patient's forehead. Thereafter the examiner moves slowly the patient's head into extension. The VP can be identified in which the SP of C5 below the index finger will subjectively glide forward in the early part and the SP of C6 at the end stage of flexion. If the middle finger is not on top of C6 the examiner had the wrong "VP". This simple and elegant tech-

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nique has its pitfalls, as the VP is not always the C7, and its identification depends on the normal function of the cervical spine. Hypomobility of C5/6 level (*e.g.,* ankylosis) may alter completely the results. Lastly, the technique is performed on sitting patients, therefore it is useless in operation rooms. It would probably be best to palpate the first rips with the middle finger and connect the thumbs in between [19].

Study's strengths and limitations

There were certain limitations to the present study. First, the study sample consisted of a low number of cadavers (39), not representative of the general population. The small sample size reduces the external validity of the findings and may limit the study's statistical power. Also, the study includes a higher proportion of female (23) compared to male (16) cadavers. This imbalance in sex distribution may also affect the findings' applicability to the general population. Another limitation is that the identification of the VP and the nail's placement was performed by a single investigator. The reliability and accuracy of this method could be influenced by inter-observer variability. It is important to note that the present sample consisted of cadavers rather than patients, which introduces a potential factor that may influence the accuracy and generalizability of the current findings. It must also be considered that the prone position with the roller below may change the visible landmarks in comparison to the sitting or standing position (the latter in anatomical standard position). As a result, the shoulder girdle glides cranially, therefore the silhouette of the cervicothoracic junction changes. Although C7 is typically described as the VP, in the present study the C7 SP was identified as the most prominent in less than 50%. The high variability of the level of projection of the most prominent SP is of immense importance for physicians during clinical examination of the spine, neck surgery, and spinal anesthesia. Further studies with a larger sample would be helpful to generalize the current findings. In conclusion, Although C7 is described as the VP, in the present study the SP of C7 was the most prominent in less than 50%. The high variability of the projection spinal level of the most prominent SP of the cervical vertebrae holds great clinical significance for spine examination, neck surgery, and spinal anesthesia.

ORCID

Trifon Totlis: https://orcid.org/0000-0001-5729-7755
Andreas Sammer: https://orcid.org/0000-0003-4789-8180
Maria Piagkou: https://orcid.org/0000-0002-4831-8005
Konstantinos Natsis: https://orcid.org/0000-0002-3077-1784
Panagiotis-Konstantinos Emfietzis: https://orcid.org/0009-0002-2630-2552
Filippos Karageorgos: https://orcid.org/0000-0002-8260-2624
George Tsakotos: https://orcid.org/0000-0001-8559-8969
George Triantafyllou: https://orcid.org/0009-0001-0122-2436
Georg Feigl: https://orcid.org/0000-0001-6984-5413

Author Contributions

Conceptualization: TT, GF. Data acquisition: GF. Data analysis or interpretation: TT, AS, MP, PKE, GF. Drafting of the manuscript: TT, AS, MP, PKE, FK. Critical revision of the manuscript: TT, AS, MP, KN, George Tsakotos, George Triantafyllou, GF. Approval of the final version of the manuscript: all authors.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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