Shoulder traction as a possible risk factor for C5 palsy in anterior cervical surgery: A cadaveric study

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Research Article

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Abstract

Background

Many risk factors for postoperative C5 palsy (PC5P) have been reported about “cord shift” after a posterior approach. However, there are few reports about shoulder traction as a possible risk factor of anterior cervical surgery. So, we tried to observe stretched nerve roots when shoulder traction was applied and to assess the risk factors for PC5P

Methods

One cadaver(A 72-year-old male) was chosen out of six that were available based on age and the presence of foramen stenosis. After dissecting sternocleidomastoid muscle of the cadaver, the shoulder joint was pulled with a force of 2, 5, 8, 10, 15, and 20 kg. Then, stretched length of the fifth nerve root was measured in the extra-foraminal zone. In addition, the same measurement was performed after cutting of the carotid artery to accurately identify the nerve root origin. After additional dissection was performed so that the superior trunk of the brachial plexus could be seen, the stretched length of the 5th and 6th nerve roots was measured again.

Results

In the first experiment, the 5th nerve root began to elongate by 2 mm at 8 kg and increased to a maximum of 5 mm. Also, after carotid artery dissection, when 8 kg of traction force was applied, it was elongated by 2 mm, and increased by up to 7 mm. After the second dissection, the length of the 5th and 6th nerve roots began to increase from 8 kg, and then increased to a maximum of 6 mm and 5 mm, respectively.

Conclusion

Although this was a cadaveric experiment, it suggests that shoulder traction could be the risk factors for PC5P after anterior cervical surgery. In addition, for patients with foraminal stenosis and central stenosis, the risk would be higher. Our results suggest the possibility that shoulder traction applied in actual surgery can lead to PC5P. Therefore, the surgeon should be aware of this, and the patient will need sufficient explanation.

Background

Postoperative C5 palsy (PC5P) is a well-known complication after cervical spine surgery, with an incidence of 0-30%. [1] The difference of incidence depends on the approach and surgical procedures. [1, 2, 3] When an isolated anterior approach was taken, the rate of palsy was 4.3%, while the rate of palsy was 10.9% with an isolated dorsal approach and 11.1% with an antero-posterior procedure. C5 Palsy occurs due to “cord shift” after dorsal decompression, as the C5 nerve root becomes more tethered compared to other cervical roots. [2, 4] Therefore, procedures such as prophylactic foraminotomy and skip laminectomy/laminoplasty have been attempted to reduce tethering of the nerve root due to cord shift. [7, 8, 9]

The “cord shift” described above is common in posterior surgery, but PCP5 may also occur after an anterior cervical operation. Therefore, studies to identify other causes have been performed and published. [2, 5, 6, 10] Among them, excessive shoulder traction for fluoroscopic imaging of the lower cervical spine was identified as a risk factor for PC5P. [10, 11, 12, 13] However, anatomical studies of shoulder traction only addressed the possibility of a stretched nerve root during shoulder retraction. [3, 10, 14] In addition, since no studies have been performed in a surgical setting, it remains unclear whether shoulder traction correlates with clinical features.

Therefore, in this study, we observed stretching of the 5th cervical root in a cadaver when shoulder traction was applied in a surgical setting. Our goal was to evaluate the possibility of shoulder traction causing PC5P in anterior cervical surgery.

Methods

Permission to perform a cadaver study was granted by the Institutional Review Board of Yonsei University College of Medicine, Seoul, Korea (2021-1893-001).

The cadaver was chosen out of six that were available for educational purpose. Most patients underwent surgery are elderly, so the 72-year-old patient was selected. Selected cadaver was confirmed presence of foraminal stenosis on oblique view by C-arm fluroscopy (C-arm). It could increase the likelihood of C4-5 being pinched in the extradural and extraforaminal zone. Therefore, PC5P might be induced by preexisting C4-5 foraminal stenosis. In addition, this would make it easier to observe stretching of the nerve root. [3, 7] Dissection was performed on the left neck of a cadaver. First using the Smith-Robinson approach [15], we identified the anterior vertebral body. Sternocleidomastoid muscles (SCM) were cut at the proximal site, so that the C5, C6 roots from the anterior scalene, could be seen. The distal part was dissected up to the supraclavicular area (to the brachial plexus superior trunk) while preserving other structures (Figure 1). To confirm the C5, C6 roots, C-arm was used to locate the C4-5 and C5-6 foramen (Figure 2).

In the supine position, we applied Buck’s traction on the cadaver’s left forearm and connected a force-gauge instrument (TS-50K, TENKYO, China) to the traction. One examiner pulled the device (on the cadaver’s left side) horizontal to the floor and upper extremity. A simultaneous counter force was applied to the foot. The other examiner pulled the right forearm with a similar counter force to obtain the same height of both shoulders (similar to shoulder traction during anterior cervical surgery) (Figure 3).

In the first experiment, the most proximal part of the C5 nerve root, originating from the anterior scalene, was marked 2 cm from the origin. The distance of the root extension was measured by pulling it with a force of 2, 5, 8, 10, 15, or 20 kg. This traction force was determined by pre-investigated values measured from anesthetized patients who underwent anterior surgery. These values were previously investigated by our institute regardless of the current experiment. The average traction force weight was 12.25 kg (8.5-14 kg) for males and 9.47 kg (8-13 kg) for females. Therefore, traction force weight of 8, 10, or 15 kg was tested, and 2, 5, or 20 kg were additionally tested to compare the minimum and maximum strains. Simultaneously, we took a C-arm image to visualize the lower cervical vertebra in the image when each force was applied. To better visualize the C5 root origin, the carotid artery was cut, and the same estimation was performed.

We next dissected the anterior scalene muscles proximally, which allowed us to visualize the origins of the C5 and C6 nerve roots from the foramen. More distal dissection was performed to observe the superior trunk of the brachial plexus where the C5 and C6 roots join distally. The length of C5 and C6 nerve root extensions was measured due to enough visualization of C5 and C6 nerve roots. In this second setting, for comfortable visualization, distal points of the C5 and C6 nerve roots were marked 2.5 cm from the proximal point.

In all experiments, a sterile skin marker was used for marking, and a surgical ruler was used to estimate the extended nerve root length. When the ruler moved due to traction force, a third examiner relocated the proximal point along the nerve root axis and the previously marked proximal point using mosquito forceps.

Results

In the oblique view (for level confirmation), height of the C4-5 intervertebral foramen was slightly lower than adjacent upper and lower foramen height, and it showed the presence of foraminal stenosis (Figure 2). According to the lateral C-arm image, the inferior endplate of the C5 vertebral body was seen when no traction force was applied. When a force of 12 kg was applied, the C6-7 intervertebral space was exposed. When the maximum traction force of 20 kg was applied, the C7 inferior endplate was visible, but the lower disk space was hidden by shoulder joint (Figure 4). Since a cadaver is more rigid than an anesthetized patient, greater forces may be required to visualize the lower cervical in cadavers.

We initially found that extended nerve length increased from 2 mm to 5 mm at the maximal traction force. After cutting the carotid artery, the length did not differ with forces of up to 10 kg. However, the length increased by 6.5 mm and 7 mm at forces of 15 kg and 20 kg, respectively. Therefore, the dissection of the soft tissue and carotid sheath needed to cut the carotid artery may have affected the movement of the nerve root.

In the second experiment, no changes in nerve length were observed for forces of up to 5 kg, but when 8 kg of traction force was applied, nerve displacements of 2.5 mm and 1 mm occurred in C5 and C6, respectively, which increased to 6 mm and 5 mm at the force of 20 kg (Figure 4, Table 1). Although the stretched length of C6 was slightly shorter at its maximum traction, it extended to a similar length as it belongs to the same superior trunk. However, the maximal increased length of C5 was slightly less than that in the first experiment. Since the proximal and distal points measured were different from the first experiment, this difference was not considered significant.

Table 1
Stretched lengths (mm) for shoulder traction forces in a cadaver.

	2 kg	5 kg	8 kg	10 kg	15 kg	20 kg
1st experiment						
C5	0	0	2	3	4	5
1st experiment, after cutting carotid artery (to better visualize the C5 root origin)						
C5	0	0	2	3	6.5	7
2nd experiment, dissection from the origin of the extraforaminal zone to the location where the superior trunk is visible (C5, C6 exposed state)						
C5	0	0	2.5	3	4	6
C6	0	0	1	4	4	5

Discussion

PC5P is a well-known postoperative complication that has been reported in many studies. The incidence of PC5P is reported to be about 0-30%, and the difference in incidence varies greatly depending on the surgical approach. [1, 2, 3]

The prognosis for PC5P has been reported to be relatively good, with an onset time mostly within a few hours to a few weeks after surgery, and spontaneous full recovery was achieved within the first 6 months in most cases. [2, 3, 5, 6, 10] However, even if the prognosis of PC5P is good, dysfunction due to PC5P may affect postoperative rehabilitation or quality of life and adversely affect the overall prognosis. Therefore, it is important to understand the etiology of PC5P and prevent it in advance.

Risk factors for PC5P include: 1) iatrogenic direct nerve root injury or intraoperative traction [16, 17]; 2) surgical strategies such as multiple segmental operation with/or posterior approach leading to extensive spinal cord shift [2, 5]; and 3) shoulder traction for positioning [10, 11, 12, 13].

Since intraoperative nerve injuries can be avoided with meticulous care of the surgeon, they are modifiable risk factors for PC5P. However, the selection of surgical strategies depends on each patient's pathology, and modifications may be limited or not possible. The overall incidence of PC5P for anterior approaches was 4.3% and that for dorsal approaches was 10.9%. According to these results, PC5P occurred more in posterior surgery. [2]

This is due to the anatomical features of the C5 nerve root. C5 dorsal rootlets were originated horizontally and shorter compared to other cervical rootlets. [18, 19] Therefore, C5 ventral rootlets appeared to become taut and easily injured after dorsal decompression.[20] Similarly, PC5P also occurred after anterior surgery due to the anatomical features described above.[21] However, "cord shift" theory focuses mainly on the posterior approach, and the relationship of anterior surgery has not been explained completely. Therefore, other risk factors of unexpected PC5P should be considered.

Excessive shoulder traction could affect both anterior and posterior surgery. Therefore, it may be a risk factor in anterior surgery. In some studies on intraoperative neuromonitoring (ION), loss of somatosensory evoked potential (SSEP) during anterior surgery returned after releasing shoulder traction. [11, 12] These studies suggest that preoperative shoulder traction may affect PC5P.

Generally, shoulder traction is used for fluoroscopic imaging of the lower cervical spine [10, 13]. Since there are no standardized criteria for traction forces, we had concerns about how much traction force should be applied. Woodroffe applied 10, 20, and 30 lb in five subjects, and then used MRI to determine the angles between the vertical spinal axis, the C5 nerve root, and the upper trunk.[10] The angle between the C5 root and the upper trunk increased with higher weight and it was statistically significant. Therefore, Woodroffe demonstrated that shoulder traction could lead to C5 nerve root tension with subsequent injury and palsy. However, since the standards of 10, 20, and 30 lb used in that study did not reflect the traction force applied in actual operations, we determined the traction forces based on the pre-investigated values from our institute. These values were measured from anesthetized patients who underwent anterior surgery.

Although we have other concerns about nerve dysfunction according to the length of cervical root elongation, there are no precise data regarding that. Some reports of peripheral nerve injuries have shown that the thresholds for nerve rupture and dysfunction are different for each nerve. [22, 23] We reviewed studies about the ulnar nerve elongation for reference data of stretched length. These studies showed increased length and strain with elbow movement, but did not provide a detailed analysis of the dysfunction associated with increased length. [24, 25] Therefore, it is not possible to know exactly how the increased length in this study affected PC5P.

However, there are some studies that can infer this. When the abduction extension cervical nerve root stress test was performed on radiculopathy patients, pain aggravation or paresthesia occurred, and under the same conditions, the cadaver nerve root was displaced by about 2 to 6 mm. [14] The results of our study showed an increase from about 2 to 6.5 mm in the 8, 10, and 15 kg traction forces, which is similar to the traction forces applied in actual surgery. Therefore, we suggest that the stretched nerve root observed in our study could cause neuropathic symptoms. In addition, since this tension was maintained during surgery, patients may progress to PC5P.

In another cadaveric study, the intradural length during shoulder traction was observed after dissecting the dural sac, and the study concluded that shoulder depression could be a risk factor for PC5P. [3] It also reported that intradural movement at the “gutter level” (the transition from inside the foramen to outside the foramen) was much more dramatic. However, that study observed the entire rootlet length regardless of the gutter level. Therefore, we observed the cervical nerve root movement grossly passed by the gutter level.

Moreover, it has been reported that the main etiology of PC5P is impairment of the C5 nerve root induced by existing C4-5 foraminal stenosis.[26] Therefore, we propose that the nerve root is more easily pinched in the gutter level if there is foraminal stenosis of C4-5. Also, most patients who underwent surgery present myeloradiculopathy, and they have both foraminal stenosis and central stenosis. In this case, the nerve root is more pinched at the gutter level, since the space of intradural rootlets is reduced. Therefore, C5 nerve root elongates more in the extraforaminal zone (passed by the gutter level), and this leads to PC5P (Figure 5). So we recommend that patients with foraminal stenosis and central stenosis are treated more gently and carefully during shoulder traction.

We have some limitation of this study. C6 extended length measured in second experiment was similar to that of the C5 nerve root. It can be used for subsequent comparative study in the future, but for now, it is insufficient to explain the significance. Secondly, study was limited in that it did not have a control group for comparison. Also, only one male cadaver is not enough to explain the effects of shoulder traction. Therefore, a serial cadaver study with a control group is needed in the future. In addition, our results could differ from real patient results, as we dissected and cut structures, such as the soft tissue, carotid artery, and SCM. Further studies are needed to overcome the limitations above.

Conclusion

The risk factors for PC5P are variable. Our study focused on the effects of shoulder traction performed during preoperative positioning. In the extraforaminal zone, the cadaver's 5th and 6th cervical nerve roots were both stretched from 2 mm to 4 mm when forces of actual surgery had been applied, suggesting that the traction force applied in actual surgery could cause PC5P. In addition, if patients with foraminal stenosis and central stenosis, this risk will be higher.

Although shoulder traction is necessary for fluoroscopic imaging of the lower cervical spine, as well as easier approach and wound closure, the surgeon should be aware of related risks and explain them to the patient.

Abbreviations

PC5P: Postoperative C5 palsy; C-arm: C-arm fluroscopy; SCM: Sternocleidomastoid muscle; ION: Intraoperative neuromonitoring; SSEP: somatosensory evoked potential

Declarations

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FDA device/drug status: Not applicable.

Ethics approval and consent to participate: All experiments were performed in accordance with relevant guidelines and regulations of our institution. Permission to perform a cadaver study was granted by the

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Consent for publication: Not applicable

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Figures

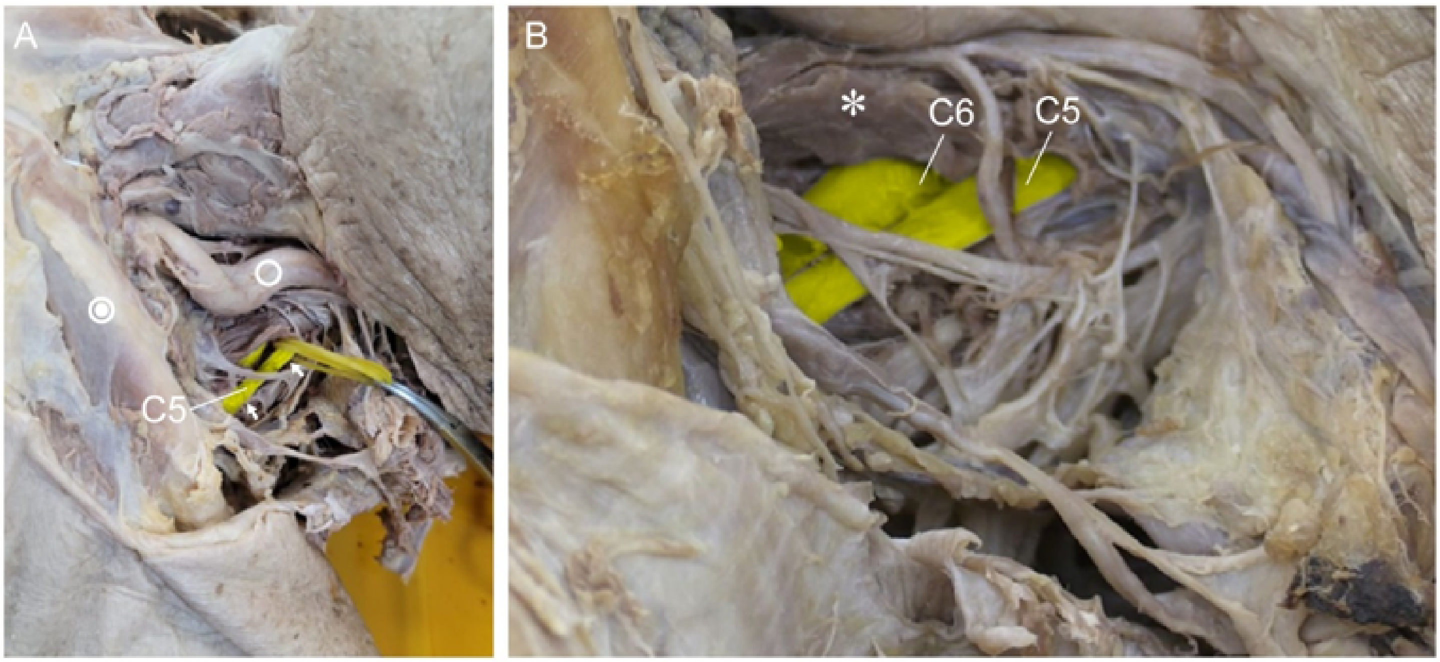

Figure 1

A (Left) Gross photo after first dissection. Rubber indicates the C5 nerve root. Single circle indicates the carotid artery, and double circle is the clavicle. **B** (Right) Lateral view of the more fully dissected left side of the neck. Asterisk indicates the anterior scalene muscle. C5 and C6 nerve roots emerging from this muscle are shown.

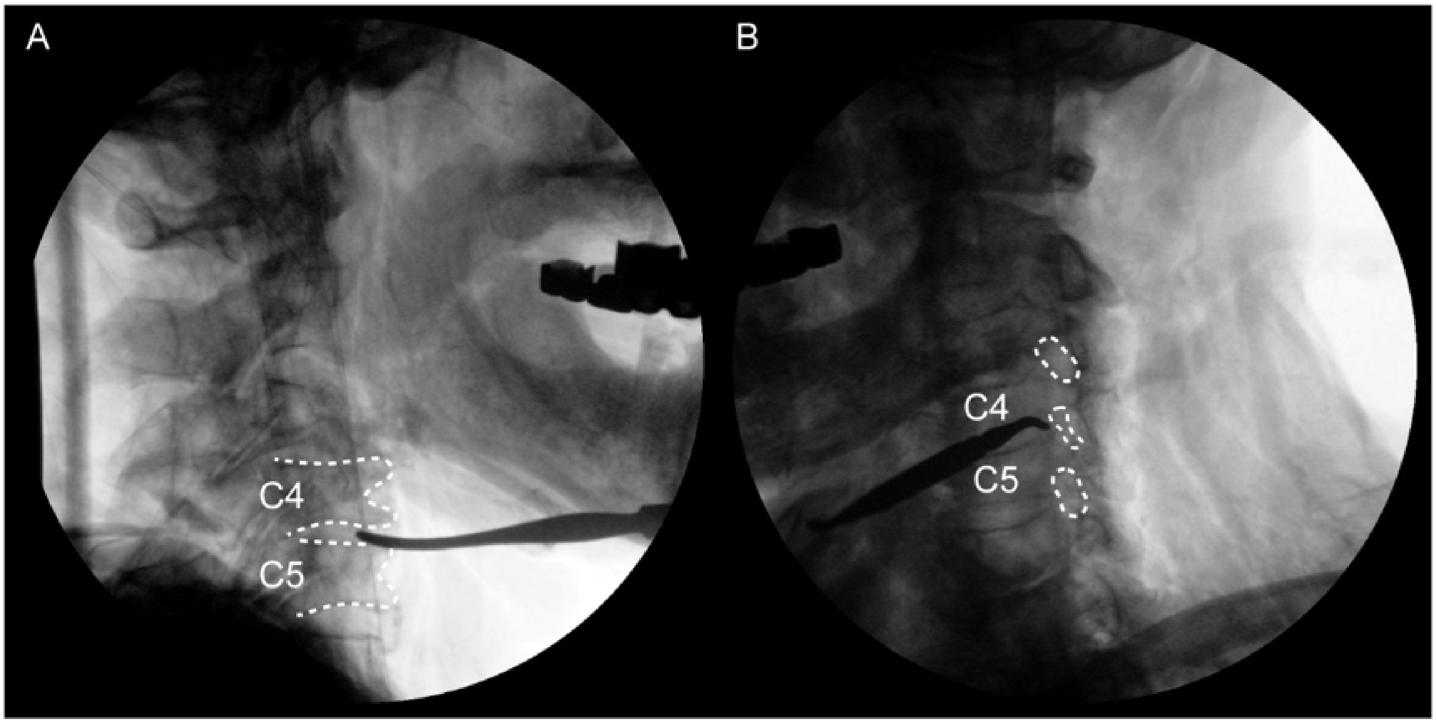

Figure 2

A (Left) Lateral view to confirm the C4-5 disk. **B** (Right) Oblique view to confirm the C4-5 foramen. The C4-5 foramen is narrower compared to the adjacent level.

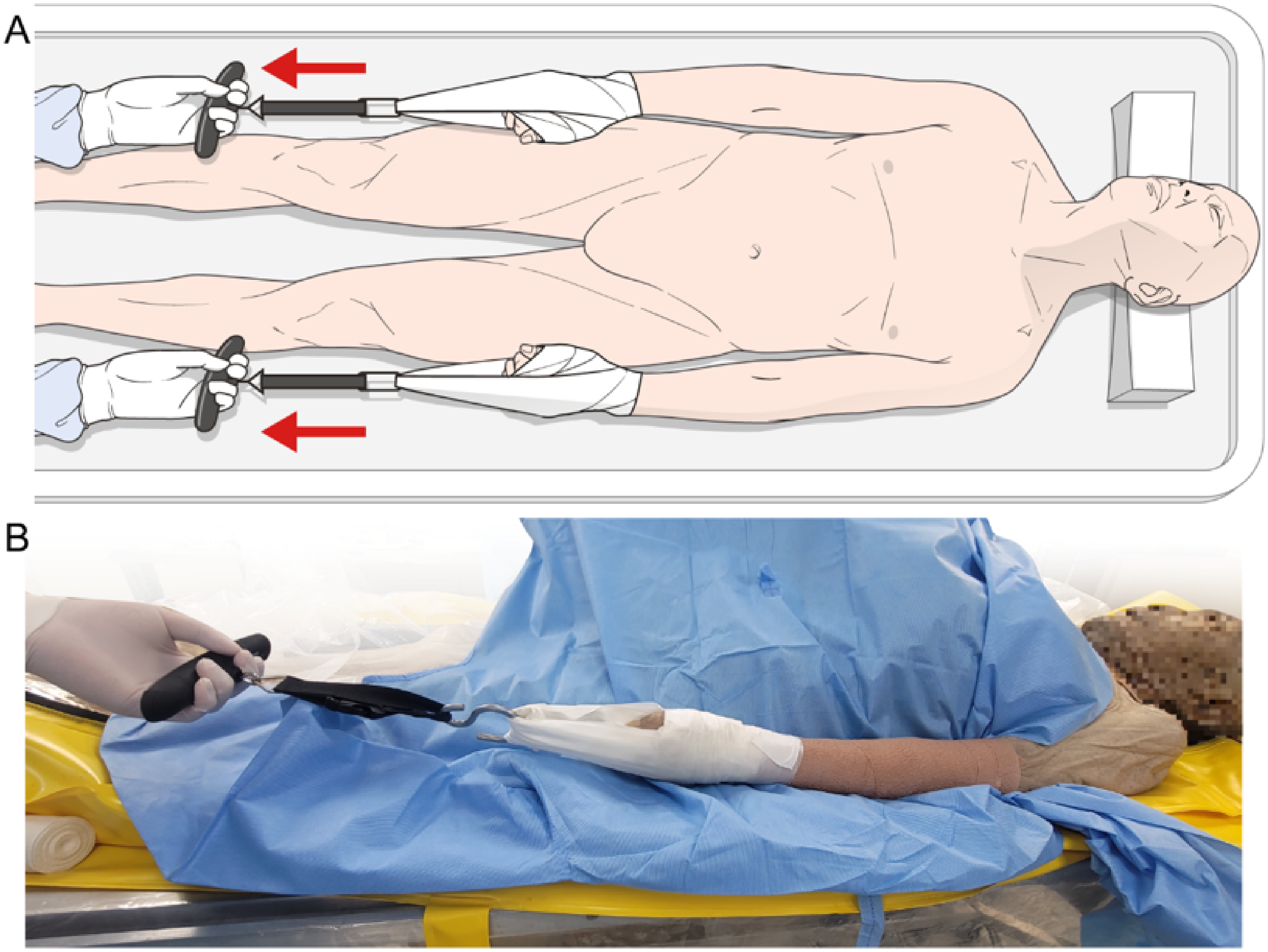

Figure 3

A, B Experimental setting after applying Buck’s traction. The left forearm of the cadaver was pulled horizontal to the floor and upper extremity.

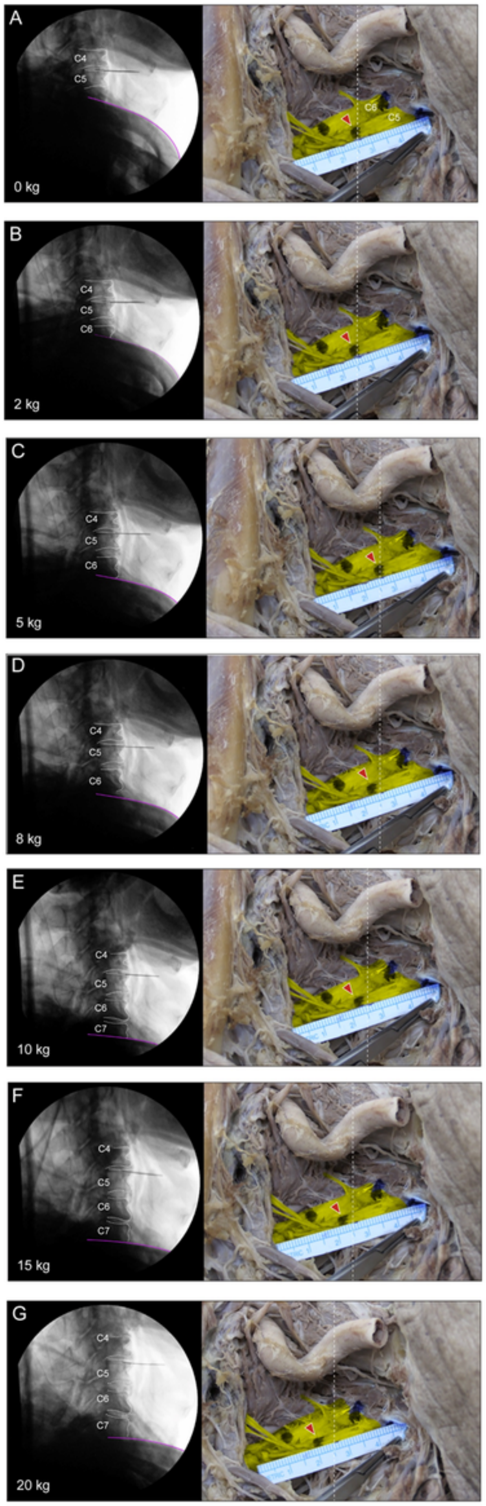

Figure 4

A-F Fluoroscopic lateral view and gross findings of a stretched root at each traction force. Indication of lateral view located in C4-5 intervertebral space and inferior purple line indicates upper margin of clavicle. Each traction force is 0, 2, 5, 12, 15, and 20 kg. As the traction force increases, the visible range of the lower cervical vertebrae increases in the lateral image, and finally, the inferior margin of the C7 endplate is visible at a force of 20 kg. The vertical dotted line on the right gross photo shows a point 2.5 cm away from the extraforaminal origin. How much the root stretches as more traction force is applied can be seen by the red arrow and the point marked on the nerve root moving away from the dotted line.

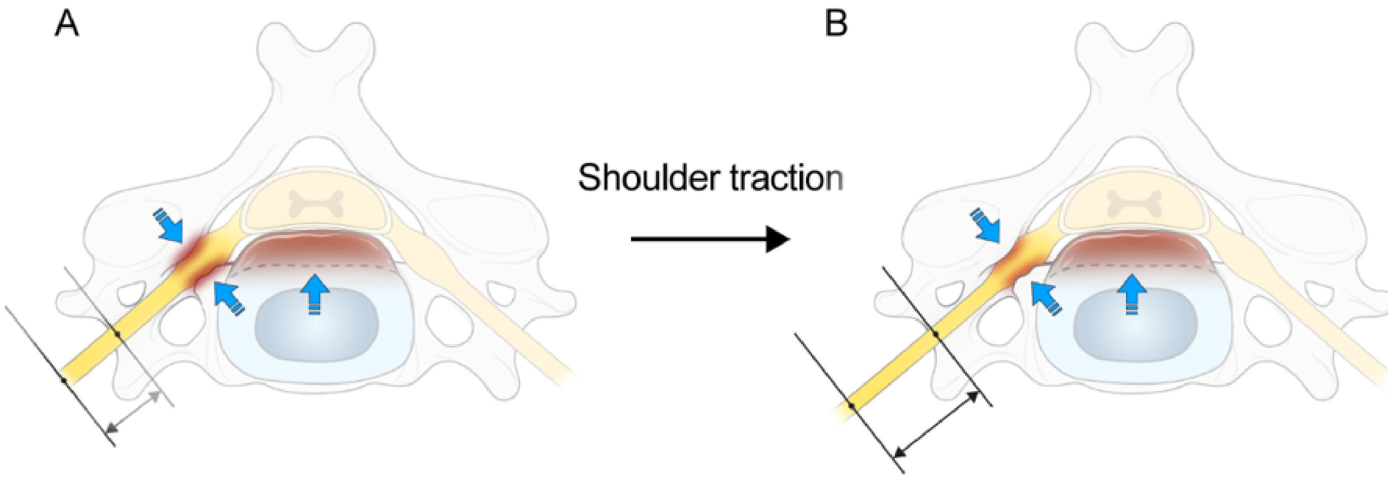

Figure 5

Schematic diagram of the stretched nerve root in the extradural and extraforaminal zone. **A** (Left) Before shoulder traction, both foraminal stenosis and central stenosis (blue arrows) are shown on the left side of picture. **B** (Right) After shoulder traction, only the nerve root in the extradural and extraforaminal zone is stretched because of a pinched “gutter level” (the transition from inside the foramen to outside the foramen) due to foraminal stenosis and cord compression.