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# Quantitative Anatomic Evaluation of Cervical Lateral Mass Fixation With a Comparison of the Roy-Camille and the Magerl Screw Techniques

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**Study Design.** An anatomic and computed tomography (CT) study of the Roy-Camille and the Magerl techniques with quantitative comparison of the safety zones of the two surgical techniques.

**Object.** The purpose of this study was to compare quantitatively the safety zones of the Roy-Camille and the Magerl techniques as a function of the vertebral level from C3–C6.

**Summary of Background Data.** The two most popular techniques for lateral mass screws are the Roy-Camille and the Magerl technique. Nerve roots, vertebral artery, facet joints, and the spinal cord are at risk during the placement of lateral mass screws. Several anatomic studies are reported, but there is no comparative and quantitative evaluation. The influence of the vertebral level was never reported.

**Methods.** Lateral mass screws were first implanted on four cervical spines according to the two surgical techniques. Screws were then extracted and their cavities filled with a blue casting medium. To determine the precise limits of each safety zone in the sagittal plane, the specimens were sectioned according to the sagittal angulation of the two screwing techniques. The correlations between the anatomic landmarks on the specimen and the anatomic landmarks on the CT scan were established. One hundred and sixty lateral mass screws were then implanted in 20 cervical spines from C3–C6. A CT was done before and after placing lateral mass screws. On the morphologic CT scan, we measured the sagittal safety angle (SSA) for each surgical technique and also performed a morphometry of lateral masses. On the control CT scan, we analyzed screws placement in relation to the sagittal safety zone.

**Results.** The mean SSA was 15.8 ± 6.3° for the Roy-Camille technique and 18.7 ± 3.8° for the Magerl technique, $P < 0.005$. With respect to the vertebral level, the Roy-Camille safety zone decreased from C3–C6 with a greater angulation at C3–C4 (20.4 ± 4.7°) than at C5–C6 (11.6 ± 4.3°), $P < 0.001$. Such variations were not observed for the Magerl technique, the SSA of which was 19.4 ± 3.6° at C5–C6 and 17.9 ± 4° at C3–C4, $P < 0.01$. Lateral masses became more elongated and thinner at the lower segment of the cervical spine with a C3–C4 height/thickness ratio = 1.1 ± 0.3 and a C5–C6 height/thickness ratio = 1.3 ± 0.2, $P < 0.005$. Roy-Camille screws (19%) were found out of the safety zone at C3–C4 whereas 37.5% were found outside at C5–C6, $P < 0.05$. We observed opposite results for Magerl screws with 38% screws out of the safety zone at C3–C4 and only 17.5% outside at C5–C6, $P < 0.05$.

**Conclusion.** The Roy-Camille technique demonstrated a progressive decrease of its safety zone from C3–C6. At C5 and C6 there is a great probability to have a transarticular screw with a Roy-Camille screw. A similar variation was not observed for the Magerl technique. These anatomic results seem to be in relation with the morphologic variability of lateral masses from C3–C6 as demonstrated by an increase of the height/thickness ratio at the lower part of the cervical spine. According to these anatomic considerations and previously published biomechanical data, Roy-Camille technique appears to be the best option at C3 and C4. On the opposite at C5 and C6, the choice is more difficult considering that there is no biomechanical difference between the two techniques and that the Magerl technique is safer but a more demanding procedure.

**Key words:** lateral mass, bone screws, morphological study, cervical vertebrae, safety zone, cervical spine fixation. **Spine 2005;30:E140–E147**

Posterior cervical plates with lateral mass fixation are currently used for posterior internal fixation of the lower cervical spine.[1–6] This technique of internal fixation has been proved to restore the stability of the cervical motion segment after traumatic or postlaminectomy injuries.[7–16] Since Roy-Camille et al[17] described the technique for the first time in 1972, many authors have described technical variations to improve the mechanical competence[18,19] or the anatomic safety.[12–22]

The anatomic structures at risk during lateral mass screwing of the cervical spine are the nerve roots, the vertebral artery, and the adjacent lateral masses.[20,21,23–25] A spinal cord injury during plate-screw fixation has never been reported in the literature. Contrary to the lumbar spine, the cervical nerve root is placed at the lower part of the intervertebral foramen.[26–28] Inside the intervertebral foramen the course of the nerve root is oblique anteriorly, laterally, and inferiorly running inside a groove on the ventral aspect of the lateral mass just behind the vertebral artery.[24,29] At the lateral part of the intervertebral foramen, nerve root divides in two branch-

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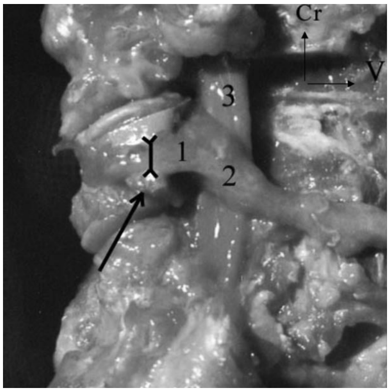


Figure 1. The nerve root runs inside a groove on the ventral face of the lateral mass. Its course is directed laterally, anteriorly, and downward. It divided in a ventral and a dorsal root. The dorsal ramus (1) located posteriorly and superiorly runs against the anterolateral corner of the base of the superior articular process just above the posterior ridge of the transverse process (arrow). The ventral ramus (2) continues the nerve root direction inside a groove formed by the two branches of the transverse process. Vertebral artery (3). Cr, cranial; V, ventral.

es[28] (Figure 1). The dorsal ramus placed posteriorly and superiorly runs against the anterolateral corner of the base of the superior articular process just above the posterior ridge of the transverse process. The ventral root placed ventrally and inferiorly continues the nerve root direction inside a groove formed by the two branches of the transverse process.[29]

According to several reported anatomic[22,30,31] and clinical studies,[1–6,10,14,17,32] the two most popular types of lateral mass screw techniques are the Roy-Camille technique, perpendicular to the posterior surface of the lateral mass, and the Magerl technique, directed 25° laterally and parallel to the facet join superiorly.

Heller et al[30] has suggested that the incidence of nerve root injury is higher with the Magerl technique than with the Roy-Camille technique. Nerve roots were placed at risk for injuries in 26.8% for the early group and 10.8% for the late group, respectively ($P < 0.005$). Xu et al[22] proposed to modify the traditional Magerl technique with higher entry point located only 2 mm inferior to the inferior edge of the superior facet. The modified screw trajectory is more cephalad just beneath the articular surface, therefore avoiding nerve root injury.

In the transverse plane the only risk is medially with the presence of the vertebral artery. On the opposite if the screw is too lateral there is no anatomic structure at risk. Ebraheim et al[23] evaluated precisely the correct location of the vertebral artery in a nice anatomic study and found that either Roy-Camille technique either Magerl technique could damage the vertebral artery with a minimal 15° lateral angulation.

The main objective of this study was to compare quantitatively the safety zone of the Roy-Camille and The Magerl techniques especially in the sagittal plane. The effect of the vertebral level on the size of the safety zone was evaluated. We also performed a morphometry of lateral masses from C3–C7.

## Materials and Methods

Twenty-four adult cervical spines were harvested from fresh human cadavers coming from the department of anatomy of the University. Each spinal segment included C2 to T1 vertebrae. Computed tomography (CT) scans were performed on a somatom 4 plus siemens (Siemens Medical System, Erlangen, Germany) with an acquisition of 2-mm thick slices. The same CT protocol was followed for both morphologic and the control CT. For lateral mass screwing we used cortical 3.5-mm titanium-threaded rods (Scient'x, Guyancourt, France).

**Procedures.** The study was divided in two parts. First, we dissected four cadaver specimens to analyze the safety zone for both surgical techniques. Second, we completed a radiologic study by CT scan before and after screws placement on 20 cervical spines.

**Surgical Anatomic Dissection Study.** The purpose was to define the Roy-Camille and Magerl safety zones on cadaver specimens. Vertebral arteries of 4 cervical spines were first injected with red color latex. Then, each cervical spine was placed in the prone position with the neck in the neutral position. After a standard posterior approach of the lower cervical spine, the posterior arch of each vertebra from C3–C6 was exposed. Articular capsules were removed allowing precise identification of the facet joint line and the lateral side of lateral mass.

The entrance point was identified on the posterior surface of the lateral mass according to the insertion technique (Figure 2). The entrance point for the Roy-Camille technique is at the center on the posterior surface of the lateral mass. The screw is directed 10° lateral and perpendicular to the posterior surface of the lateral mass. For the Magerl technique the screw insertion site is 1–2 mm medial and cranial to the center of the lateral mass. The screw is directed 25° lateral and directed parallel to the facet joint line, 45° cranial to the posterior surface of the lateral mass.

All screw holes were drilled with a 2.2-mm drill bit. The length of the screw thread inserted inside the lateral mass was precisely measured with a gauge to get a bicortical purchase. Titanium screws (3.5 mm) were inserted according to the Roy-Camille and Magerl recommendations with regard to screw positioning (Figures 3 and 4).

As described by Jonsson and Rauschning,[31] after screw placement we extracted the screws and filled their cavity with a blue casting medium. The specimens were then sectioned in the sagittal angulation of the screw technique from the entry point on the posterior aspect of the lateral mass: 10° laterally for the Roy-Camille technique and 25° laterally for the Magerl technique.

We could then determine the precise limits of each safety zone in the sagittal plane. The Roy-Camille safety angle was defined from the center of the posterior aspect of the lateral mass and limited by the nerve root groove superiorly and the tip of the lower lateral mass inferiorly (Figure 5a). The Magerl safety angle was defined from a point located 1 mm superiorly to the center of the posterior aspect of the lateral mass and limited by the inferior articular process superiorly and the presence of the dorsal branch inferiorly (Figure 5b).

**Radiologic Study (Twenty Cervical Spines).**

*Morphologic CT Scan.* After harvesting cervical spines from cadavers, an initial CT was completed to:

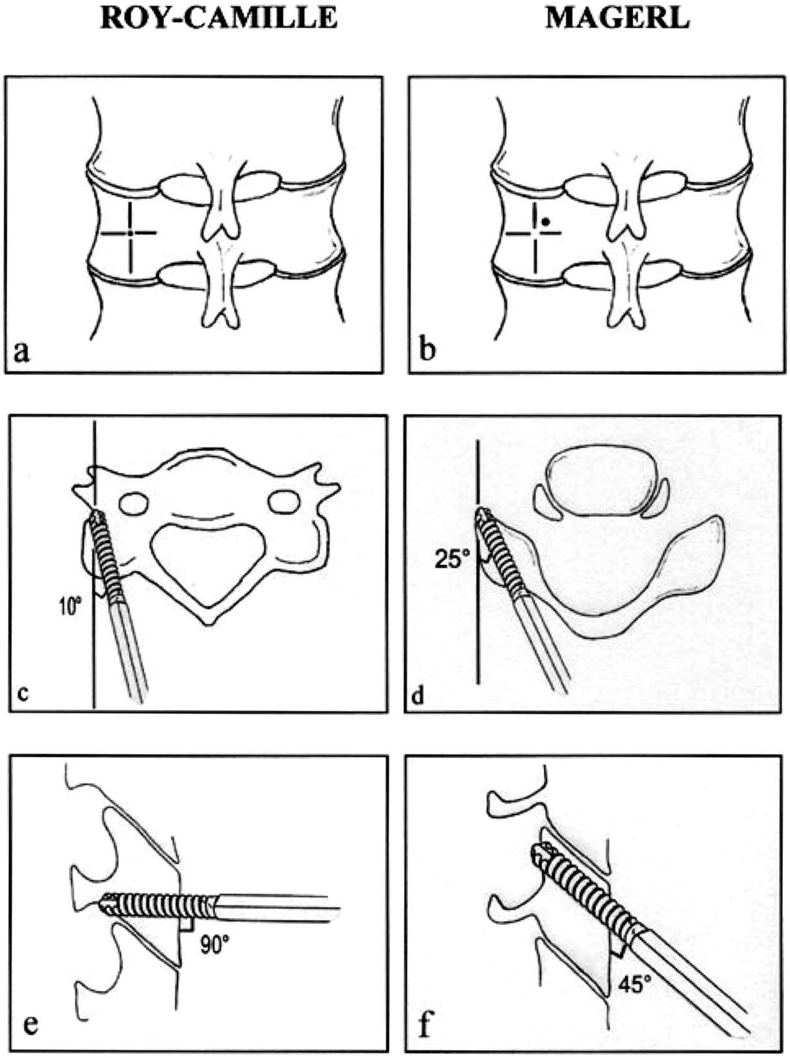


Figure 2. Description of the two screw techniques. Each surgical technique is characterized by an entry point on the posterior aspect of the lateral mass and by the two angulations in the sagittal and transversal plane.

- Measure the sagittal safety angle (SSA) of each screwing technique by multiplanar reconstructions. Sagittal slices were performed in the plane of the screw technique. The Roy-Camille safety angle was measured on sagittal slices directed 10° laterally and passing by the center of the posterior aspect of the lateral mass (Figure 6a). The Magerl safety angle was measured on sagittal slices directed 25° laterally and passing by a point located 1 mm medially to the center of the posterior aspect of the lateral mass (Figure 6b). The inferior and superior limits of the SSA are precisely demonstrated on CT sections in Figure 6 for each surgical technique.

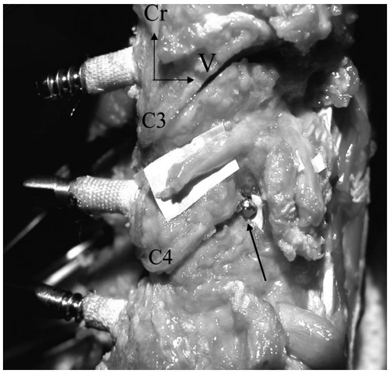


Figure 3. Ventral purchase of Roy-Camille screws (arrow) has to be precisely located at the junction between the lateral mass and the transverse process below the groove of the nerve root. Cr, cranial; V, ventral.

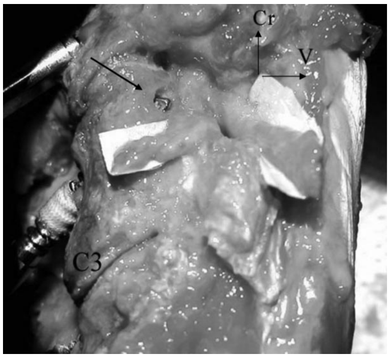


Figure 4. Ventral purchase of Magerl screws (arrow) has to be precisely located at the antero-supero-lateral aspect of the lateral mass just above the course of the dorsal ramus. Cr, cranial; V, ventral.

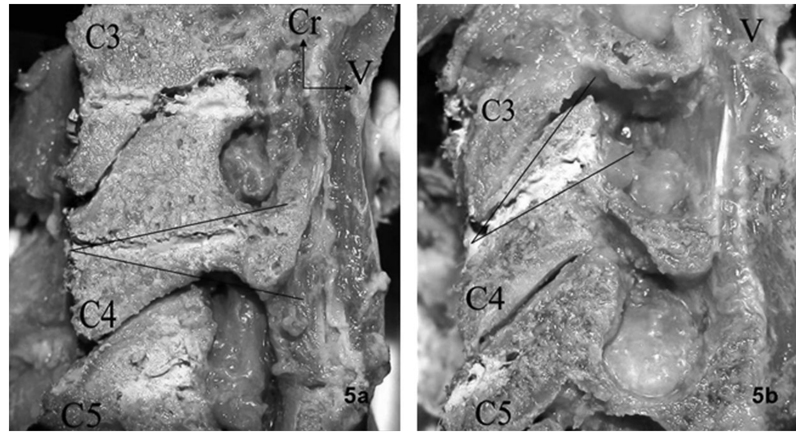


Figure 5. Photographs showing sagittal sections of cervical spines. Spine specimens were sectioned from the entry point on the posterior aspect of the lateral mass and 10° laterally for the Roy-Camille technique (**a**) and 25° laterally for the Magerl technique (**b**). The SSA are delimited with black arrows for the two screwing techniques.

- Perform a morphometry of lateral masses from C3–C7 with measurements of the width, height, and thickness (Figure 7). On a true sagittal CT slice passing by the center of the lateral mass, the height was the distance between the two adjacent joints on the posterior aspect of the lateral mass, and the thickness was the distance between the dorsal and the ventral cortex at the central part of the lateral mass. The width was measured on a transversal CT slice passing by the center of the lateral mass and was the distance between the medial and the lateral cortex at the central part of the lateral mass.

*Implantation of Lateral Mass Screws.* One hundred and sixty lateral mass screws were implanted on twenty cervical spines from C3–C6 according to the two screw techniques as described above (80 for each surgical technique). The same individual (C. B.) inserted all articular screws to minimize the effect of variation in the surgical technique.

*Control CT Scan.* A second CT was achieved to check the screw placement. In particular, sagittal and transverse orientations of lateral mass screws were analyzed. We also noted whether the screw was or was not in the safety zone that we had previously defined. In addition we measured (Figure 8) the following:

- The distance between the tip of the screw and the vertebral artery. For Roy-Camille screws the distance was calculated between the tip of the screw and the foramen transverse and
- The effective screw length between dorsal and ventral cortices.

**Statistical Analysis.** Student *t* tests were performed to compare the safety angle among surgical technique and vertebral level.

All *P* values were two-sided and considered statistically significant for a $P < 0.05$.

## Results

Twenty cervical spines were included in the statistical analysis. The average age of the subjects was 73 ± 6 years; there were 10 males and 10 females. Two hundred lateral masses from C3–C7 were analyzed for the morphometric portion of the study. One hundred and sixty lateral mass screws were inserted from C3–C6 to determine the effect of screw technique on the apparent safety zone for insertion.

### *Sagittal Safety Zone*

Values per vertebral level are summarized in Table 1 for each screwing technique. The SSA was 15.8 ± 6.3° for the Roy-Camille technique and 18.7 ± 3.8° for the Magerl technique, $P < 0.005$. Regarding the influence of the vertebral level, the Roy-Camille SSA demonstrated higher angulation at C3–C4 (20.4 ± 4.7°) than at C5–C6 (11.6 ± 4.3°), $P < 0.001$. The contrary was observed for the Magerl SSA, which was greater at C5–C6 (19.4 ±

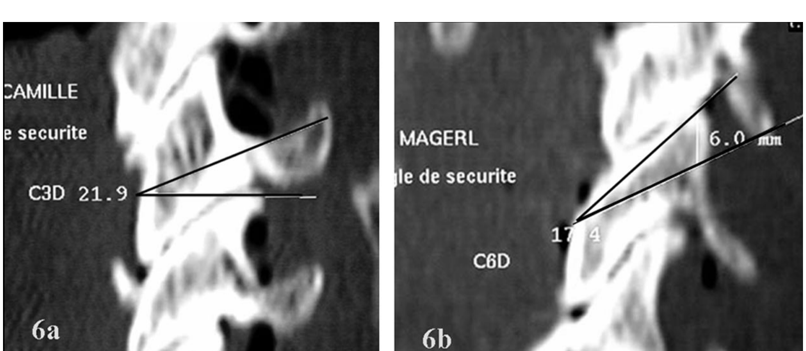


Figure 6. After the surgical anatomic study we could establish correspondences with landmarks on the CT scan. The SSA for Roy-Camille (**a**) was defined from the center of the posterior aspect of the lateral mass and limited by the nerve root groove superiorly and the tip of the lower lateral mass inferiorly. The SSA for Magerl (**b**) was defined from a point located 1 mm superiorly to the center of the posterior aspect of the lateral mass and limited by the upper lateral mass superiorly and the presence of the dorsal branch inferiorly. The dorsal root is obviously not visible on the CT scan. We used data from a anatomic study by Ebraheim et al[37] concerning the mean height of the dorsal ramus exactly at the ventro-lateral corner of the lateral mass just above the transverse process. We then reported the height of the dorsal ramus according to the vertebral level on the CT scan (C3 = 2.2 mm, C4 = 1.6 mm, C5 = 1.7 mm, C6 = 1.2 mm).

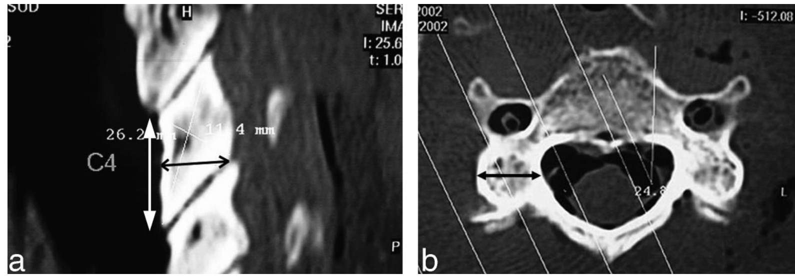


Figure 7. Morphometry of lateral masses from C3–C7. The height and the thickness were measured on a sagittal slice by the center of the center lateral mass (**a**). The width of lateral masses was measured on a transversal slice by the center of the lateral mass (**b**).

3.6°) than at C3–C4 (17.9 ± 4°), $P < 0.01$. There was no significant difference according to the gender.

#### *Morphometry of Lateral Masses*

Mean values are summarized in Table 2 for each vertebral level from C3–C7. The width was larger at C5–C6 (12.5 ± 1.3 mm) than at C3–C4 (11.2 ± 1.4 mm), $P < 0.001$. Lateral masses were larger for men (12.5 ± 1.7 mm) than for women (11.5 ± 1.3 mm), $P < 0.005$.

Lateral masses were thicker at C3–C4 (10.6 ± 1.3 mm) than at C5–C6 (9.8 ± 1.2 mm), $P < 0.001$. No significant difference was found according to gender.

Lateral masses are roughly rhomboid at C3–C4 and become more elongated and thinner at C5–C6 and particularly at C7 as suggested the analysis of the height/thickness ratio. The height/thickness ratio was 1.13 ± 0.27 at C3–C4 and 1.29 ± 0.22 at C5–C6, $P < 0.005$ (Table 2).

#### *Control CT Scan (Tables 3–5)*

First, regarding the angulations of screws, there was <2° difference in both planes with regard to theoretical data for the Roy-Camille technique and <5° for the Magerl technique, which is a more difficult surgical procedure. This suggested that most screws were correctly placed according to original recommendations for screw insertion.

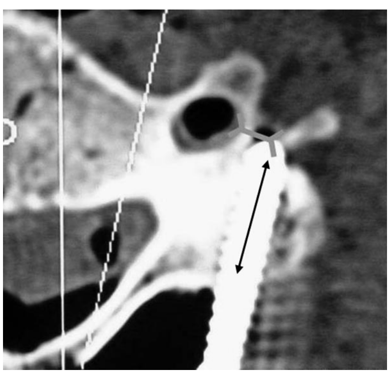

Figure 8. Control CT scan showing a Roy-Camille screw. After screw placement we measured bone purchase (double arrow), screws angulations in both sagittal and transverse planes, and the distance between the tip of the screw and the vertebral artery.

**Table 1. Sagittal Safety Angle (°) for the Roy-Camille and the Magerl Techniques**

| | Roy-Camille | Magerl |
|---|---|---|
| C3 | 21.2 ± 3.9 (13.5–29) | 18 ± 4 (9.9–26.2) |
| C4 | 18.8 ± 4.9 (8.9–28.6) | 17.7 ± 2.8 (12–23.4) |
| C5 | 12.4 ± 4.2 (4–20.7) | 18 ± 2.5 (13.1–23) |
| C6 | 11.9 ± 5.6 (0.7–23.1) | 20.7 ± 3 (14.7–26.7) |

Note: For each value mean, SE ± and range are mentioned.
Graph below shows influence of the vertebral level on the sagittal angle of the safety zone (°) for Roy-Camille and Magerl techniques.

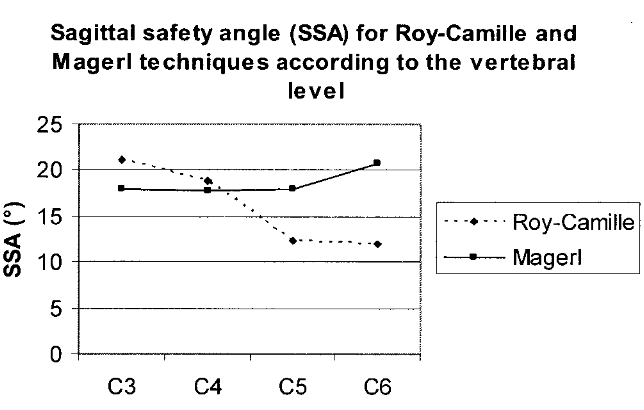


**Table 2. Morphometry of Lateral Masses from C3–C7**

| | Width * | Height * | Thickness * |
|---|---|---|---|
| C3 | 11.1 ± 1.3 (8.5–13.7) | 12.5 ± 2.1 (8.3–16.7) | 10.9 ± 1.4 (8.2–13.7) |
| C4 | 11.2 ± 1.1 (9.1–13.4) | 12 ± 2.1 (7.8–16.3) | 10.2 ± 1.1 (8–12.4) |
| C5 | 12.3 ± 1.5 (9–15.6) | 13.1 ± 2.1 (8.9–17.2) | 10.1 ± 1.3 (7.5–12.7) |
| C6 | 12.9 ± 1.4 (10.1–15.7) | 13.5 ± 2.1 (9.2–17.8) | 9.5 ± 1.1 (7.3–11.6) |
| C7 | 13.2 ± 1.9 (9.3–17.1) | 13.9 ± 2.7 (8.5–19.3) | 9.1 ± 1.4 (6.3–11.9) |

Note: For each value mean, standard error ± and range are mentioned.
* In millimetres.
Graph below shows height/thickness ratio of lateral masses from C3–C7

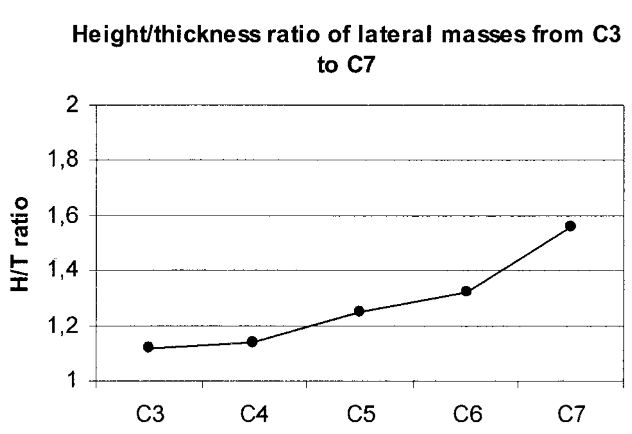

**Table 3. Control CT Scan**

| | Roy-Camille | Magerl |
|---|---|---|
| Sagittal angulation * | 1.3 ± 5.6 (−12.5 to 12.6) | −37.7 ± 8.5 (−20.7 to −54.7) |
| Transversal angulation * | 11.3 ± 5.4 (0.4–22.2) | 20.2 ± 5.1 (10–30.4) |
| Bone purchase † $P < 0.001$ | 10.7 ± 1.6 (7.5–14.1) | 14.1 ± 2.6 (9.1–17.3) |
| Distance between the tip of the screw and the vertebral artery † $P < 0.01$ | 3.2 ± 1.9 (0–6.9) | 5.7 ± 2.7 (0.3–11.2) |

Note: For each value mean, standard error ± and range are mentioned.
* In degrees.
† In millimeters.

**Table 4. Results of Lateral Mass Screws in Relation with the Safety Zone of Each Screwing Technique**

| | Roy-Camille (80 Screws) | | Magerl (80 Screws) | |
|---|---|---|---|---|
| Proportion of 'out of safety' screws | 27.5% | | 26.3% | |
| Results according to the anatomical risk | Risk of nerve root injury, 2.5% (2/80) | Joint line violation, 25% (20/80) | Risk of nerve root injury, 21% (17/80) | Joint line violation, 5% (4/80) |

Bone purchase, verified on the CT scan, was significantly longer for the Magerl technique (14.1 ± 2.6 mm) than for the Roy-Camille technique (10.7 ± 1.6 mm), $P < 0.001$. Independent of the screwing technique, we also noted that bone purchase was longer at C5–C6 (13.7 ± 2 mm) than at C3–C4 (12.8 ± 1.8 mm), $P < 0.05$.

The distance between the tip of the screw and the vertebral artery was significantly longer for the Magerl technique than for the Roy-Camille technique. No difference was observed according to the vertebral level.

Roy-Camille screws (27.5%) and Magerl screws (26.3%) were found out of the sagittal safety zone, which was not statistically significant. Results are summarized in Table 4. The most Roy-Camille screws found out of the safety zone were located beneath the inferior limit of the SSA, resulting in a violation of the facet join. For the Magerl technique the most screws found out of the safety zone were also located beneath the inferior limit of the SSA with a risk of nerve root injury. Table 5 demonstrated the influence of the vertebral level.

## ■ Discussion

Our findings concerning the anatomic risk for each surgical technique are concordant with the literature.[21,22,30]The measurement of the sagittal angle of the safety zone provided a quantitative analysis of anatomic risk, permitting the comparison between the two screwing techniques. We found that for the Magerl technique the SSA is nearly constant from C3-C6 around 18–20° whereas it reduced considerably for the Roy-Camille technique at the lower part of the cervical spine. As reported previously,[30,31] the main anatomic risk for the Roy-Camille technique is violation of the adjacent lateral mass especially at the lower part of the cervical spine C5-C6. Screws violating the articular surfaces should be avoided. Mechanical conflict with the facet joints may produce neck pain, adjacent segment degeneration, and pullout of the screw. Roy-Camille screws are unlikely to cause nerve root injury because they point midway between the nerve bundles.

For the Magerl technique the main risk is to damage the nerve root. The technical challenge is not to be too high, to avoid violation of facet join, and not to be too low, to avoid nerve root injury. In our study the Magerl technique appeared to be safer at C5 and C6 than at C3 and C4, whereas the difference between C3–C4 and C5–C6 safety angle was minimal around 2°. In a com-

**Table 5. Proportion of lateral mass screws outside the sagittal safety zone according to the vertebral level**

| | C3–C4 | C5–C6 |
|---|---|---|
| Roy-Camille, $P < 0.05$ | 17.5% (7/40) | 37.5% (15/40) |
| Magerl, $P < 0.05$ | 35% (14/40) | 17.5% (7/40) |

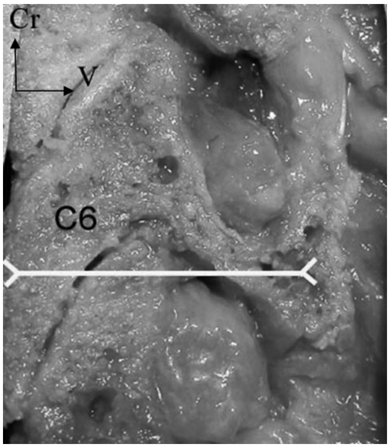


Figure 9. At C5–C6, lateral masses became more elongated with a longer oblique facet join. The tip of the superior articular process was found close to the horizontal plane of the nerve root groove. This provides therefore a significant reduction of the Roy-Camille safety zone and explains the high frequency of transarticular Roy-Camille screws (arrow) at these levels.

parative study, Xu et al[25] found 95% of nerve violation occurred with the Magerl technique.

The effect of the vertebral level on the anatomic risk seems to be in relation with the progressive elongation of lateral masses from C3–C7[33,34] as demonstrated by the increase of the height/thickness ratio. At C5 and C6 the nerve root groove and the facet join are located in a very close transverse plane, reducing considerably the Roy-Camille safety zone with a high rate of transarticular screws at these levels (Figure 9).

We have to note that the radicular risk is overestimated in anatomic study compared with clinical study.[32] This is particularly true in our study. We considered a risk of nerve root injury on the CT scan when the tip of the screw was found in the direction of the theorical placement of the nerve root on the CT scan. However, a strictly bicortical purchase without over-penetration of the ventral cortex doesn't lead to nerve root injury even if the tip of the screw is just in front of the nerve.

In the transversal plane the risk is damage of the vertebral artery medially and fracture of the lateral mass laterally. Ebraheim et al[21,23] evaluated the relationship between the vertebral artery foramen and the midpoint of the cervical lateral mass. According to these researchers, an orientation 15° laterally seems sufficient to avoid vertebral artery. In our study we found only one violation of the transverse foramen in 160 lateral mass screws. The Roy-Camille screw should therefore be placed in the center of the posterior aspect of the lateral mass, perpendicular to the vertebral pane with 15° lateral angulation rather than 10°.

Although the fact that the sagittal safety zone reduced considerably at C5 and C6 for Roy-Camille technique, we did not observe a greater proportion of "out of safety" screws for Roy-Camille technique. This is certainly related to the easier technical aspect of Roy-Camille screw technique than of Magerl technique. For the Roy-Camille technique the only angulation is 10° laterally whereas for the Magerl technique we have to perform two angulations in the sagittal (45°) and in the transversal plane (25°).

As demonstrated previously by Heller et al,[35] a bicortical purchase provides a greater pullout resistance for lateral mass screws with a gain of approximately 30%. In addition the mean thickness of lateral masses from C3-C6 is only 11.9 mm providing a very short bony purchase for unicortical screws. For these reasons we performed bicortical bone purchase in this study.

From a biomechanical point of view we reported a biomechanical study with a comparison of the Roy-Camille and the Magerl screwing techniques.[36] The difference between pullout forces of the Roy-Camille and the Magerl techniques was not as significant as it has been previously suggested in the literature. The mean force required for screw pull-out was 266 ± 124 N for the Roy-Camille technique and 231 ± 94 N for the Magerl technique. It was interesting to note the influence of the vertebral level: Roy-Camille screws revealed significant greater pullout strengths (+23%) at C3-C4 levels (299 ± 114 N) than Magerl screws (242 ± 97 N) but no significant difference between the two surgical techniques was observed at C5–C6 levels (Roy-Camille, 236 ± 122 N; Magerl, 220 ± 86 N).

According to these anatomic and biomechanical considerations, it appears that Roy-Camille technique is the best option at C3 and C4 vertebral levels: stronger, safer, and easier to perform. At C5–C6 the choice is more difficult. The choice is related to surgeon experience, considering that there is no biomechanical difference between the two techniques and that the Magerl technique is safer but a more demanding procedure.

## ■ Conclusion

The Roy-Camille technique demonstrated a progressive decrease of its safety zone from C3–C6. Such variations were not observed for the Magerl technique.

These anatomic results seem to be in relation with the morphologic variability of lateral masses from C3–C6 as demonstrating the increase of the height/thickness ratio at the lower part of the cervical spine.

According to these anatomic considerations and previously published biomechanical data, Roy-Camille technique appears to be the best option at C3 and C4. At C5 and C6, the choice must be left to surgeon experience considering that we found no biomechanical difference between the two techniques and that the Magerl technique is safer but a more demanding procedure.

### ■ Key Points

- The measurement of the sagittal angle of the safety zone provided a quantitative analysis of anatomical risk permitting the comparison between the two screwing techniques and the influence of the vertebral level.
- For the Magerl technique this angle is nearly constant from C3 to C6 around 18–20°, whereas it reduced considerably for the Roy-Camille technique from 20° to 12° at the lower part of the cervical spine.
- Lateral masses are roughly rhomboid at C3 and C4 and become more elongated and thinner at C5 and C6 and particularly at C7 as suggested the analysis of the height/thickness ratio.
- According to anatomical and biomechanical data Roy-Camille technique appears to be the best option at C3 and C4: stronger, safer and easier to perform. At C5 and C6 the choice is related to surgeon experience considering that there is no biomechanical difference between the two techniques and that the Magerl technique is safer but a more demanding procedure.

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