Anatomic Safe Zone of Pin Insertion Point for Distal Clavicle Fixation

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Clavicle fracture is the most common childhood fracture and one of the most common fractures in adults. Only some types of distal clavicular fractures, and dislocation of the acromioclavicular joint, require internal fixation. Many surgeons prefer closed pinning; however, the difficulty inserting many of the various kinds of pins from acromion into the medullary canal, of the distal clavicle, means the likelihood of iatrogenic complications from repeated drilling is heightened. The purpose of the present study was to establish what would be the optimum insertion point and direction for safe intramedullary pinning of the distal clavicle. Embalmed cadaveric shoulders (32) were studied. A bone window was created at the distal one-thirds of the clavicle, ~1.5 cm medial from the conoid tuberosity - as wide as could be freely, retrogradely drilled into the medullary canal of the distal clavicle. A 2.0-mm Kirschner wire was inserted until it penetrated the acromion. The point of emergence was recorded as ratio compared with the acromial width and length in coronal and sagittal planes, respectively. K-wire directions were measured as the angle between the K-wire and the reference line from the anterosuperior tubercle of the clavicle to the anterior angle of the acromion. The process was repeated until the acromion fractured. 304 drillings were performed on 32 specimens. The length of the sagittal vs.*coronal pin insertion point from the anterior* vs. *lateral borders of the acromion divided by its length* vs. *width averaged 0.325 $\pm$ 0.04 and 0.397 $\pm$ 0.09, respectively. The angle of the K-wire and the reference was 7.69 $\pm$ 3.04 and 14.59 $\pm$ 4.34 degrees in the coronal and horizontal planes, respectively. At 8 and 10 drillings survival was 0.72 (95%CI: 0.53-0.84) and 0.41 (95%CI: 0.24-0.57), respectively. The optimum pin inserting point for fixation of distal clavicle fracture and acromioclavicular joint dislocation is 32.5% and 39.7% of acromial length and width, respectively. If a 2.0-mm K-wire is used for fixation, drilling should not be repeated drilled more than 8 times to avoid sudden, high risk iatrogenic acromial fracture.*

Keywords: *Kirschner wire, Clavicle, Insertion point*

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One in 20 of all fractures[1], and as many as 44% of shoulder girdle injuries[2], involve the clavicle. It is the most common childhood fracture[3]. Only some types of distal clavicular fractures, and dislocations of the acromioclavicular joint, require internal fixation. A number of techniques have been described for the treatment of distal clavicle fracture including; cerclage sutures[4], intramedullary devices (Steinmann pin, K-wire, Knowles pin, Perry pin, modified Hagie pins or Rush pin) and plate fixation[5-9].

Many surgeons prefer intramedullary pinning; however, the difficulty inserting many of the various kinds of pins from the acromion into the medullary canal, of the distal clavicle, means the likelihood of iatrogenic fracture complications is heightened. The purpose of the present study was to establish what would be the optimum insertion point and direction for safe intramedullary-pinning of the distal clavicle.

Material and Method

Thirty-two embalmed cadaveric shoulders, still attached to the chest wall, were used for the present

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study. The experiment was performed in the same manner for each specimen. Two palpable anatomic landmarks (*i.e.* the anterosuperior tuberosity of the medial end of the clavicle and the anterior angle of the acromion) were identified on each specimen and used as reference lines. A bone window was created at the distal one-third of the clavicle, ~1.5 cm medial from the conoid tuberosity, leaving the anterior cortex of the clavicle intact.

A bone window was created as wide as could be freely, retrogradely drilled into the medullary canal of the distal clavicle to the acromion. A 2.0-mm Kirschner wire (K-wire) was then retrogradely drilled into the medullary canal of the distal clavicle through the bone window (Fig. 1). After the K-wire emerged through the acromial surface, the subacromial space was checked to be sure no part of the K-wire had penetrated the space.

The point of emergence of the K-wire on the superior surface of the acromion was recorded. The ratio of the sagittal and coronal plane was used in order to decrease the effect of the inevitable variation in size. The point of emergence of the K-wire in the coronal plane was recorded as the coronal portal insertion ratio (CPIR), which was the distance from the lateral border of the acromion to the point of emergence (w) divided by the acromion width in the mid-portion (W) (Fig. 2). The point of emergence of the K-wire in the sagittal plane was recorded as the sagittal portal insertion ratio (SPIR), which was the distance from the anterior border of the acromion to the point of emergence (l) divided by the acromial length in the mid-portion (L) (Fig. 3).

The directions of the K-wire in relation to the reference line (AB) (Fig. 2) were recorded both in the coronal and horizontal planes as the coronal pin angle (CPA) and the horizontal pin angle (HPA), respectively (Fig. 2, 4).

After the attempt was recorded, the K-wire was removed and randomly, retrogradely drilled through the bone window until an acromial fracture occurred. Each point of emergence was recorded. The area available for intramedullary pinning of the distal clavicle, without deviation of the K-wire from the medullary canal or damaging the surrounding structures was called the "safe portal". The drillings which penetrated the subacromial space were excluded from the determination of the safe portal and its direction, but these were included when determining the survival rate after repeated drillings. Mean $\pm$ SD and 95% confidence interval (CI) were presented to describe all continuous

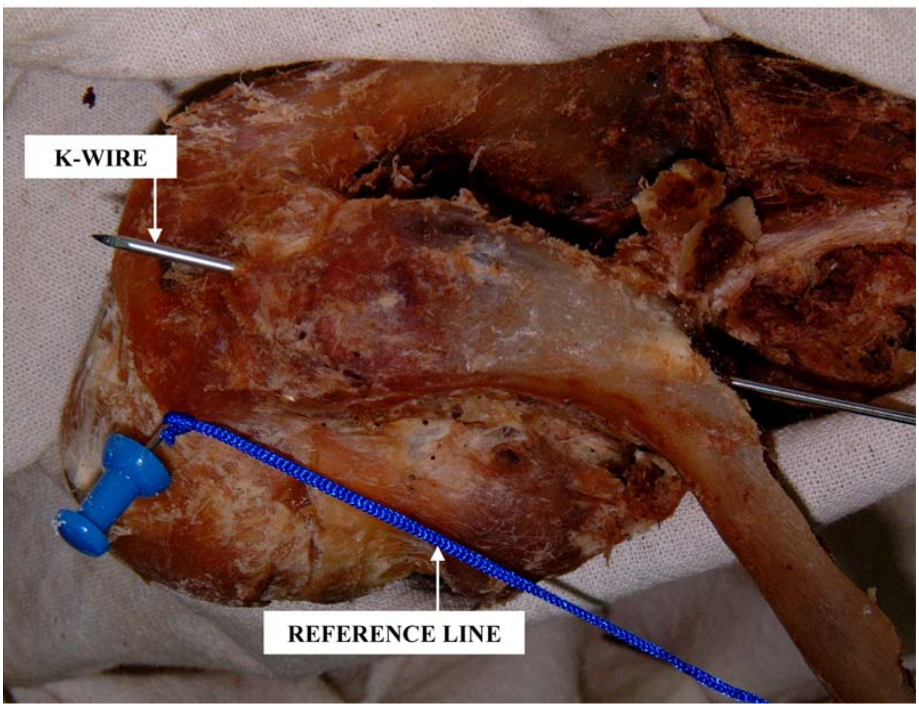

Fig. 1 A 2.0-mm Kirschner wire retrogradely drilled through the bone window emerges at the superior surface of the acromion in an embalmed cadaveric shoulder

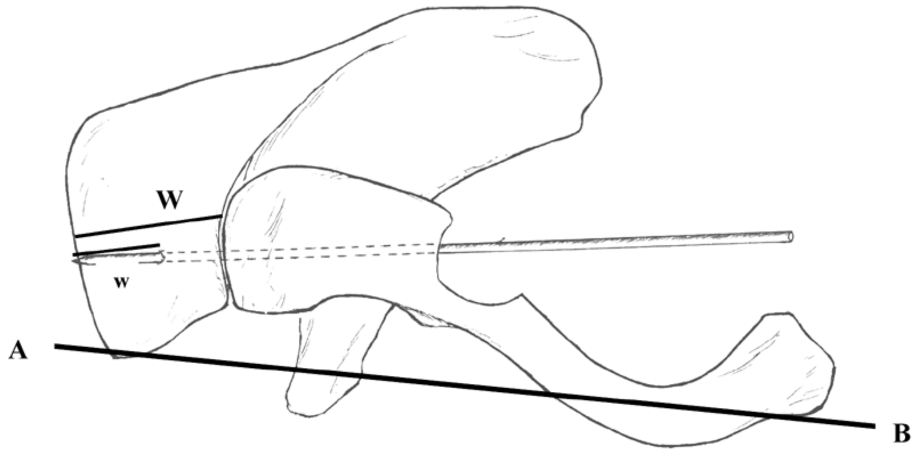

Fig. 2 Schematic diagram of the superior view of the acromioclavicular joint showing reference line (AB) and measurement of the coronal portal insertion ratio (CPIR - length "w" divided by length "W"). The measurement of the horizontal pin angle (HPA), angle between the Kirschner wire and the reference line in the horizontal plane

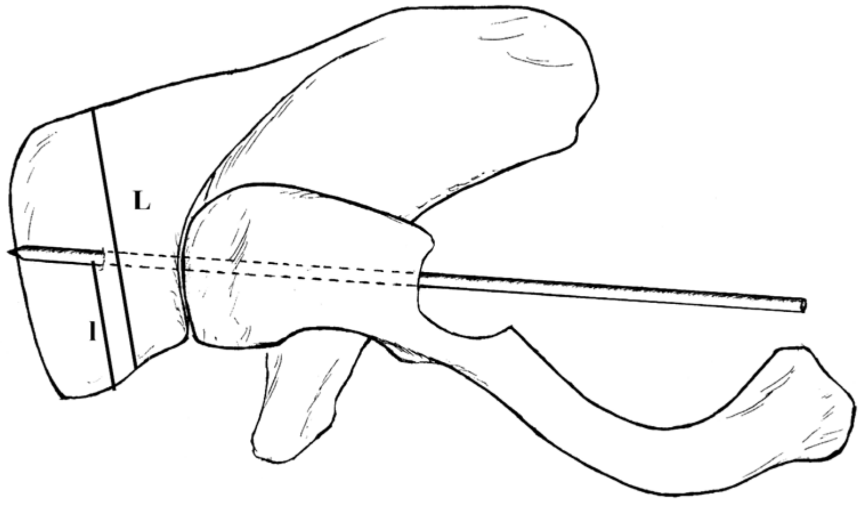

Fig. 3 Schematic diagram of the superior view of the acromioclavicular joint showing the measurement of the sagittal portal insertion ratio (SPIR - length of "l" divided by length of "L")

variables. Survival rate of aeromion fracture was estimated by Kaplan-Meier method.

Results

Safe portal and its directions

The data of 304 drillings on 32 specimens were included to determine the safe portal and its directions (Table 1). Fourteen drillings were excluded because part of the K-wire penetrated into the subacromial space. The average CPIR, SPIR, CPA and HPA was 0.397 $\pm$ 0.09, 0.325 $\pm$ 0.04, 7.69 $\pm$ 3.04 and 14.59 $\pm$ 4.34 degrees, respectively. The effect of the K-wire angle on the likelihood of fracture and no fracture was compared using the paired t test. The mean CPAs in the fracture vs non events was significantly higher ($p < 0.05$), but the difference in HPAs between these two groups was not significant ($p = 0.10$).

Survival times for repeated drilling

Survival was based on 318 drillings. The number of drillings of the K-wire until the acromial was fractured averaged 9.8 (range, 4 to 12). According to

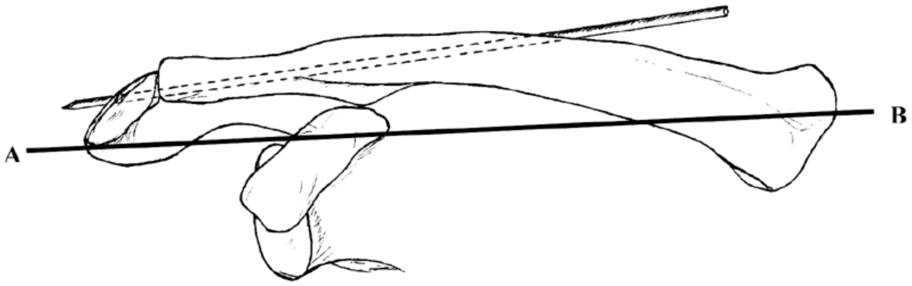

Fig. 4 Schematic diagram of the anterior view of the acromioclavicular joint showing the reference line (AB) and measurement of the coronal pin angle (CPA - the angle between the Kirschner wire and the reference line in the coronal plane)

the survival analysis, the incidence density was 0.11 (95%CI: 0.72-0.15) sample-counts. The survival rate at 4, 6, 8, and 10 drillings was 0.97 (0.89-0.99), 0.88 (0.70-0.95), 0.72 (0.53-0.84), and 0.40 (0.24-0.57), respectively (Table 2). No acromial fractures occurred with less than 4 drillings but predominated between 4 and 12 drillings. All acromial fractures occurred at the superomedial part of the acromion, which articulates with the distal end of the clavicle. The survival rate suddenly decreased between 8 and 10 drillings (Fig. 5).

Discussion

Of the various instruments, intramedullary pinning of the distal clavicle is preferred. The difficulty, however, is defining the safe portal and its direction. The acromion is a thin and flat bone. The clavicle is curved, oval, and subcutaneous along its entire length and there are important neurovascular structures that pass beneath it. Moreover, there is angulation between these bones and motion of the acromioclavicular joint. Therefore, deviation of the intramedullary pin from the clavicle can penetrate the skin or damage neurovascular structures.

In the operative procedure for intramedullary fixation of the distal clavicle, surgeons have to control the pin direction into the medullary canal of the distal clavicle to avoid injuring the surrounding soft tissue. Fluoroscopy is usually used to control pin direction. Many reinsertions of the pin can produce iatrogenic fractures of the acromion or clavicle.

An optimum entry point and direction for intramedullary pinning of the distal clavicle has several clinical implications vis- -vis the risk of acromial fracture and neurovascular injury from misdirection of the pin. The safe portal based on the present results was 39.7 and 32.5 percent of the acromial width and length, when measured from the lateral and anterior border, respectively. The appropriate directions of the pin were 7.69 and 14.59 degrees in relation to the reference

Table 1. Portal insertion ratio and its directions

	Means ± SD
CPIR	0.397 ± 0.09
SPIR	0.325 ± 0.04
CPA (degree)	7.690 ± 3.04
HPA (degree)	14.590 ± 4.34

CPIR, coronal portal insertion ratio; SPIR, sagittal portal insertion ratio; CPA, coronal pin angle; HPA, horizontal pin angle

Table 2. Survival rate and number of repeated drilling

Repeated drillings	Survival rate	Standard error	95%CI
4	0.968	0.030	0.798-0.995
6	0.875	0.058	0.700-0.951
8	0.718	0.079	0.529-0.842
10	0.406	0.086	0.238-0.567
12	0.000	-	-

CI, confidence interval

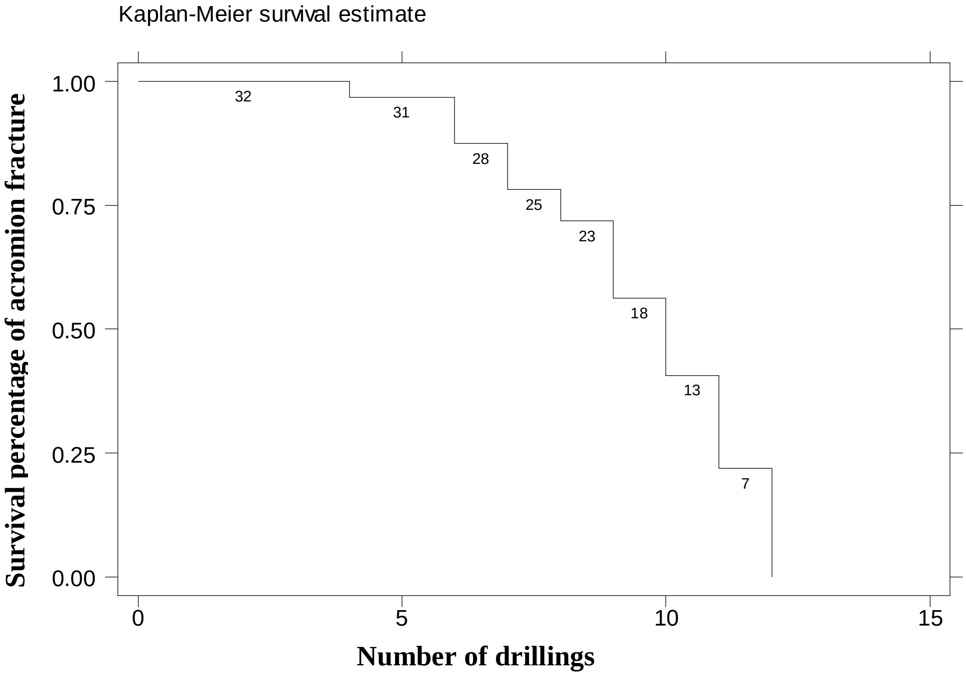

Fig. 5 Graph of the survival percentage and their corresponding number of repeated drillings. The line shows a decreasing survival rate with an increasing of number of drillings

line in the coronal and horizontal planes, respectively. Surgeons should take note of the K-wire directions, especially in the coronal plane to avoid an increased risk of an iatrogenic acromial fracture. These safe portals and directions will provide a greater probability of pinpointing the medullary canal of the distal clavicle and for placement of various types of intramedullary pins.

The second part of the results, the survival rate repeated at 8 and 10 drillings was 0.72 and 0.41, respectively, suggesting the risk of acromial fracture after repeated drillings (*i.e.* > 8) was suddenly high. None of the specimens could tolerate more than 12 drillings and all acromions fractured at the superomedial part which articulates with the distal end of the clavicle.

These results have limited clinical implications because there are many types and sizes of pins. Moreover, the intramedullary pinning for distal clavicular fractures or dislocations of the acromioclavicular joint usually inserts antegradely, from the acromion to the distal clavicle. In the authors' experience, other types of iatrogenic fractures occurred when antegradely fixed to the distal clavicle; such as the fracture of the distal end of the clavicle. The results in this part can only be applied to a 2.0-mm K-wire fixation, so further study is required for the other types of fixation.

In the present study, the authors designed the data collection in a ratio scale to decrease the statistical effect of any size variation. The other factors that have contributed to the effect were motion of the acromioclavicular and sternoclavicular joints.

Conclusion

Based on the present results, the authors recommend a safe portal insertion point for distal clavicle fixation at 39.7 and 32.5 percent of the acromial width and length, respectively. The directions of the pin are 7.69 and 14.59 degrees with respect to the reference line in the coronal and horizontal planes, respectively. If a 2.0-mm K-wire is used for fixation, it should not be drilled more than 8 times to avoid sudden, high risk iatrogenic fracture.

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ตำแหน่งปลอดภัยในการยึดกระดูกไหปลาร้าส่วนปลายเข็ม

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กระดูกไหปลาร้าหักจัดเป็นกระดูกหักที่พบบ่อยที่สุดในเด็ก และเป็นกระดูกหักที่พบบ่อยชนิดหนึ่งในผู้ใหญ่ แต่มีบางชนิดของกระดูกไหปลาร้าส่วนปลายหัก และการเคลื่อนหลุดของข้อ acromioclavicular เท่านั้นที่ต้องรักษาโดยการยึดตรึงกระดูก ศัลยแพทย์ส่วนใหญ่นิยมการใช้ลวดยึดตรึงกระดูกโดยไม่ต้องเปิดแผลผ่าตัด แต่การยิงลวดจากกระดูก acromion ไปยังส่วนปลายของกระดูกไหปลาร้ายากและมีโอกาสเกิดภาวะแทรกซ้อนได้จากการยิงลวดซ้ำ จุดประสงค์ของงานวิจัยนี้ต้องการหาตำแหน่งที่ปลอดภัยของการยิงลวดยึดตรึงบริเวณ ปลายกระดูกไหปลาร้า โดยทำการวิจัยในศพดอง 32 ตัวอย่าง ด้วยการเจาะรูบนกระดูกไหปลาร้าที่บริเวณรอยต่อ หนึ่งในสามนับจากส่วนปลายโดยห่างจากปุ่ม conoid ประมาณ 1.5 ซม. โดยเหลือขอบกระดูกทางด้านหน้าไว้ แล้วจึงยิงลวดยึดตรึงกระดูกขนาด 2 มม. ย้อนทางผ่านรูที่เจาะไว้จนทะลุกระดูก acromion บันทึกตำแหน่งที่ลวดทะลุ acromion เป็นสัดส่วนในระนาบหน้าหลัง และระนาบซ้ายขวา บันทึกแนวของลวดยึดตรึงเทียบกับเส้นอ้างอิงที่ลาก จากปุ่มกระดูกที่ปลายด้านในของกระดูกไหปลาร้าไปยังมุมด้านหน้าของกระดูก acromion หลังจากนั้นจะทำการยิงซ้ำร่วมกับการบันทึกข้อมูลของการยิงทุกครั้ง ข้อมูลจากการยิงลวด 304 ครั้งใน 32 ตัวอย่าง พบว่าตำแหน่งของลวด ในระนาบหน้าหลัง และระนาบซ้ายขวา คือ 0.325 ± 0.04 และ 0.397 ± 0.09 ตามลำดับ แนวของลวดยึดตรึงเมื่อเทียบกับแนวอ้างอิงในระนาบซ้ายขวาและแนวระดับ คือ 7.69 ± 3.04 องศา และ 14.59 ± 4.34 องศา ตามลำดับ อัตรารอดจากกระดูก หักจากการยิงลวดยึดตรึงซ้ำ 8 และ 10 ครั้ง เท่ากับ 0.72 (ค่าความเชื่อมั่นที่ 95% อยู่ระหว่าง 0.53-0.84) และ 0.41 (0.24-0.57) ตำแหน่งที่เหมาะสมกับการยิงลวดยึดตรึงเพื่อรักษากระดูกไหปลาร้าส่วนปลายหัก และในข้อ acromioclavicular หลุดอยู่ที่ประมาณ 32.5% และ 39.7% ของความยาวและความกว้างของกระดูก acromion ตามลำดับ ถ้าใช้ลวดยึดตรึงขนาด 2 มม. ไม่ควรยิงลวดซ้ำเกิน 8 ครั้งเพราะความเสี่ยงของกระดูก acromion หักจะสูงขึ้น