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Study of Different Types, Linear and Angular Measurements of Coracoid Process in Different Planes with its Clinical Implication

[1]Azra Mubeen Karnul, [2]Shashi Bhushan Gollapalli, [3]Chaitanya Krishna Murthy and [4]K. Thomas Manoj

[1]Department of Anatomy, Sri Devraj Urs Medical College, Kolar, India
[2]Department of Anatomy, Pes Institute of Medical Sciences and Research, Kuppam, India
[3]Hassan Institute of Medical Sciences, Hassan 573201, India
[4]Department of Anatomy, Mallareddy Institute of Medical Sciences, Hyderabad, India

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Corresponding Author
K. Thomas Manoj,
Department of Anatomy, Mallareddy Institute of Medical Sciences, Hyderabad, India

Author Designation
[1]Professor
[2,4]Associate Professor
[3]Assistant Professor

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ABSTRACT

Coracoid process (C.P) is projected part of scapula from its antero-lateral aspect, having proximity with ligamentous and neurovascular structures. Its tip appears in 5 different shapes. Angulations of 2 parts (superior pillar and inferior pillar) of C.P play a vital role in its position and inclination. C.P is involved in various pathological conditions like subcoracoid impingement syndrome, coracoid fracture, anterior shoulder instability, rotator cuff tears and used in reconstruction surgeries. Knowing its angulations help radiologist in proper angulation of beam of radiations for optimum visualization of C.P and for assessing proneness of diseases around shoulder joint and for planning before taking for surgeries. To assess different types of C.P, to compare morphometric and angular measurements in each type of C.P on both sides. 200 dry Scapulae were placed in 3 different planes and images were taken. Then studied in an app 'Image J'. Linear measurements and angular measurements of both processes in relation to Glenoid plane in coronal, axial and sagittal planes were studied. By using SSPS7.7, results are mentioned in average with standard deviations. Chi square test is conducted of comparing various measurements and angulations for significance. Type II was most the commonest type of C.P and type III was least in occurrence (53% and 5.5%). LxWxH of superior and inferior pillars were 3.6×1.4×0.65 cms and 1.14×2.0×0.8 cms, respectively. Superior and Inferior pillars were largest in length in type I CP on both sides and in type V on both sides p-0.003 and 0.0179, respectively. Both pillars were widest in type I C.P 3.5±0.3cms and 2.0±0.2 cms. Mean angles of inferior pillar in 128°, 137° and 54° in saggital, coronal and axial planes respectively. Superior pillar's mean angle in axial plane was 134°. In coronal plane inferior pillar showed highest angle was in type IV CP (142° and 145.3°respectively on each side) and lowest in type V CP (127.7° and 129° respectively on each side). This finding was highly significant with p-0.0004 and 0.008. This parameters may help surgeons in deciding size and orientation of screws. Angulation of C.P can be utilized by radiologist for proper angulation of beams of radiations during assessment.

INTRODUCTION

Coracoid process (CP) is a very important land mark in shoulder region, often referred as 'light house' as it is proximal to neurovascular, ligamentous and muscular structures and acts as anchor to the later structures mentioned[1]. CP has the following parts: inferior pillar/vertical prosses and superior pillar/horizontal process. Both processes make obtuse angulation with each other as the inferior pillar runs upwards and medially and superior pillar changes direction to anterolaterally resulting in curved axis of CP. Size and angulations of CP will guide us in determining the position of C.P like inferior tilting. Position of C.P affect subacromial space by influencing the attachment of corocoacromial ligament[2]. CP is involved in various pathological entities like subcoracoid impingment syndrome, coracoid fracture, anterior shoulder instability, rotator cuff tears and employ for reconstruction surgerie[3,4]. Detail morphological assessment of CP will help surgeons to avoid iatrogenic fractures, injuries to surrounding soft tissue and to reduce post operative complications like secondary fractures and loss of fixation[5].

Various studies have been done on coracoid process morphology using dry bones, fresh cadavers and computed tomography. However most do not provide comprehensive reports on entire coracoid anatomical dimensions and angulations. Coracoid morphology influence inclination of coracoacromial ligament which could lead subacromial arch modifications, progressing to degenerative changes of rotator cuff[2]. Surgical procedure at tip of vertical process has greater risk of injury of lateral cord and base of CP there is greater risk of injury of axillary nerve[6]. Regardless of this known fact, less studies have been done so far on CP.

Coracoid fracture, especially basal type which is involving glenoid cavity of scapula represents a severe form of injury and treated by screw fixation[4]. Size of screw to be selected and direction of screw during fixation is determined by size and angular orientations of the CP[7].

We propose a novel method to measure angulations of CP based on computerized software 'image J' analysis of digital images. This study will be helpful for radiologist in diagnosing cases of subcoracoid impingment syndrome and also orthopedician in reconstructive surgeries and screw fixation

Aims and objective: To classify different types of coracoid process and study various parameters of coracoid process (CP) like length, width, thickness of vertical and horizontal part of CP. To find out any variation in measurements at right and left side. To study angulations of coracoid process with emphasis on angulations of it in 3 different standard planes which will help radiologist in finding out angulations of beams of radiations during radiological assessment and which will also have implication during assessment in suspected cases of subcoracoid impingment syndrome and in planning of management of coracoid fractures and for reconstruction surgeries which may be needed in various pathologies around shoulder.

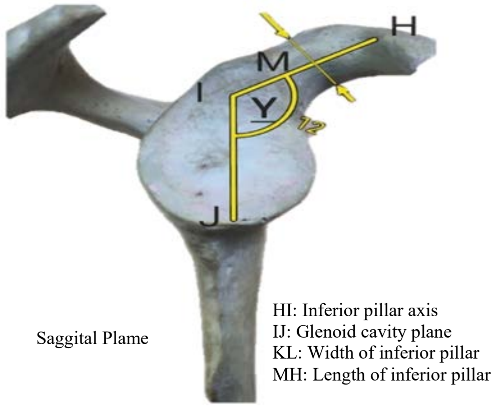
MATERIALS AND METHODS

Methodology: Two Hundred Dry Scapulae will be procured from departments of anatomy of East point college of medical sciences and research centre, Bangalore and PES Medical college, Kuppam. Different types of coracoid process depending upon their shape were noted. Types of CP are as follows: Type I coracoid process is shaped like Figure of 8, Type II Coracoid process is elongated shaped i.e length is 3 times longer than breadth of CP, Type III is shorter i.e length is not 3 times of breadth, Type IV was drop shaped i.e narrower at upper part and broader in the lower part in 8%. Type V wedge shaped i.e broad or blunt at upper end and narrow at lower part of CP. Measurements like length(L), breadth(B) and thickness(T) of superior pillar and inferior pillar of CP will be taken with digital vernier caliper.

Distinct feature coracoid process is being due to its projection and the bend, dividing this process into further 2 pillars: inferior pillar which is vertically directed and superior pillar which is directed horizontally antero-lateral wards. To measure angular orientation of these 2 pillars of coracoid process, scapula were placed in the same position as it is in radiological examination in live subjects. Digital images of all scapulae will be obtained in standard planes which are described in the literature[7,9] and measured in reference to axis of glenoid cavity(X). These planes are useful during surgeries and in radiological analysis. To achieve the standard planes, scapula was placed in 3 different ways:

- **Coronal plane:** Scapula is observed from posteriorly in coronal position of scapula. Glenoid axis is obtained by joining line superior and inferior points on glenoid surface (Fig. 3)
- **Saggital plane:** Glenoid cavity and lateral border of scapula faces the observe Glenoid axis is obtained by line passing vertically through glenoid cavity and lateral border of scapula (Fig. 2)
- **Axial plane:** Glenoid cavity faces the laterally and scapula is observed from above displaying supra spinatous fossa. Glenoid axis is obtained by drawing a line perpendicular to the vertical line running vertically from supraglenoid point to ground (Fig. 1 and 4)

Angle between inferior pillar of CP and glenoid cavity were measured in all 3 planes i.e. coronal,



Vertical process angulation with glenoid cavity (Y)

Fig. 1: Superior pillar linear measurements

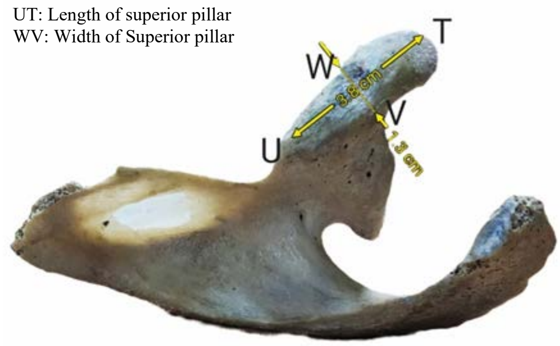
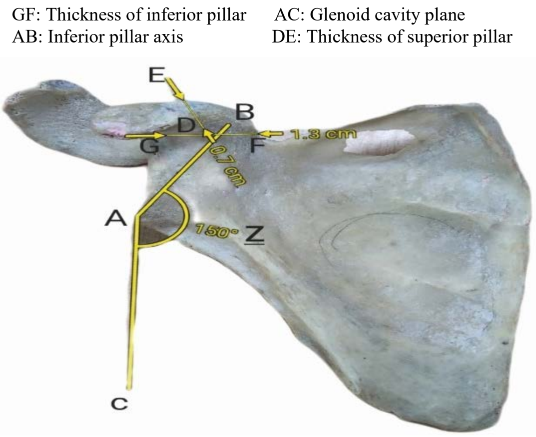
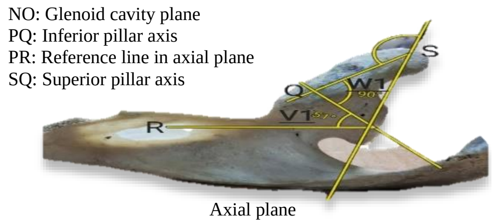


Fig. 2: linear measurements and angulation of inferior pillar-Y



Vertical process angulation with glenoid cavity (Z)

Fig. 3: Inferior pillar linear meaurements and its angulation-Z



Vertical process angulation with glenoid cavity (V1)
Horizontal process angulation with glenoid cavity (Y)
Interpillar bend angulation (W1)

Fig. 4: Superior pillar angulation(Y), Inferior pillar angulation(V1) and interprocess/Bend angle(W1)

saggital and axial planes. Angle between superior pillar of coracoid process and glenoid cavity was measured in axial plane. Bend of the CP angle is measured by lines passing through long axis of superior pillar and inferior pillar in axial plane.

Different angles were measured with the help of digital image analysis software Image J [Java based image processing program developed at national institute of health and laboratory of optical and computational instrumentation (LOCI, University of Wisconsin)]. Angulation of bend/elbow of coracoid process called as inter pillar angle or bend angle will also be measured. Non damaged scapula and nonpathological scapulae are included.

Statistical analysis: Statistical tools used is SSPS software version 7.7. Results were mentioned in average with standard deviations. Chi square test was conducted of comparing various measurements and angulations for significance, which was set to <0.05 level.

RESULTS

Types of coracoid process: Type I coracoid process was observed in 22% of scapula. Type 2 Coracoid process was most common in occurrence, seen in 53% of sample. Type 3 was seen in 5.5%. Least frequent type of CP was type 3. Type IV in 8% and type V observed in 11.5%. Frequency of each type of CP with right and left side, has been shown in Table 1. There is no significant difference was noted.

Morphometric measurements of coracoid process: Linear parameters like length, width and thickness are listed in Table 2 and 3.

The mean length of superior and inferior pillar of CP are 3.6±0.45 and 1.14±2.0 cm, respectively. Superior and Inferior pillars were longest in length on type I of CP on both sides and in type V on both sides p-value 0.003 and 0.0179, respectively. Shortest on right side on type IV 0.8±0.2 cm and left side on type III 0.8±0.3 cms.

The mean width of superior and inferior pillar 1.7±1.2 cms and 2.0±0.36 cms, respectively. Width

Table 1: Distribution of study subjects with Classification of coracoid process

	Classification					
	I (n = 44)	II (n = 106)	III (n = 11)	IV (n = 16)	V (n = 23)	
Sides	N (%)					p-value
LEFT	21 (47.7)	55 (51.9)	5 (45.5)	9 (56.2)	10 (43.5)	0.914
RIGHT	23 (52.3)	50 (48.1)	6 (54.5)	7 (43.7)	13 (56.5)	

P<0.05 statistically significant

Table 2: Distribution of study subjects according to All Parameter variables with classification on right side

	Classification					
	I (n=23)	II (n=51)	III (n=6)	IV (n=7)	V (n=13)	
Parameter	(Mean±SD)					p-value
Superior pillar						
Length	3.9±0.3	3.6±0.5	3.5±0.4	3.4±0.5	3.5±0.4	0.0300*
Width	1.7±2.4	1.1±0.4	0.9±0.2	1.1±0.1	1.1±0.3	0.03*
Thickness	0.7±0.1	0.6±0.2	0.7±0.2	0.5±0.1	0.6±0.2	0.4294
Angle- axial plane	130.8±8.5	131.8±7.3	129.2±10.6	127.4±4.9	133.1±9.7	0.5638
Inferior pillar						
Length	1.1±0.6	1.3±0.7	1.4±0.4	0.8±0.2	1.6±0.7	0.004*
Width	2.9±0.4	2.0±0.3	2.1±0.2	2.3±0.1	1.9±0.3	0.4947
Thickness	0.8±0.1	0.7±0.1	0.7±0.2	0.6±0.1	0.8±0.2	0.5301
Angle-sagittal plane	124.9°±8.2	128.7°±8.5	125.5°±6.6	126.6°±3.7	128.3°±9.4	0.3929
Angle-coronal plane	138.0°±10.6	134.5°±11.7	130.5°±7.9	142.8°±7.4	129.8°±15.1	0.008*
Angle- axial plane	57.8°±6.6	55.7°±8.4	57.5°±7.2	57.7°±10.1	55.1°±9.7	0.8033
Interpillar bend angle	70.3°±7.1	69.5°±7.8	70.5°±7.0	69.7°±14.7	76.6°±7.8	0.1055

All linear values are in centimeters

Table 3: Mean and SD Distribution of study subjects according to All Parameter variables with Classification on left side

	Classification					
	I (n = 21)	II (n = 55)	III (n = 5)	IV (n = 9)	V (n = 10)	
Parameter	(Mean±SD)					p-value
Superior pillar						
Length	3.5±0.3	3.7±0.4	3.4±0.6	3.7±0.1	3.5±0.4	0.004*
Width	1.7±0.2	1.2±0.3	1.1±0.2	1.1±0.1	1.2±0.3	0.01*
Thickness	0.5±0.2	0.6±0.2	0.6±0.1	0.6±0.1	0.7±0.2	0.2205
Angle-axial plane	133.8°±8.8	135.1°±9.1	125.6°±10.5	132.8°±8.7	134.1°±9.6	0.2768
Inferior pillar						
Length	1.1±0.4	1.3±0.5	0.8±0.3	1±0.1	3.5±6.2	0.0179*
Width	2.0±0.2	1.9±0.3	1.7±0.4	2.1±0.5	1.9±0.9	0.3657
Thickness	08±0.2	0.8±0.1	0.9±0.1	0.8±0.1	0.7±0.2	0.6941
Sagittal plane angle	129.5°±4.8	129.4°±8.6	132.4°±4.3	129°±2.4	130.7°±13.0	0.9304
Coronal plane angle	145.7°±11.2	138.2°±11.1	140.4°±2.9	145.3°±5.3	127.7°±12.2	0.0004*
Axial plane angle	55.3°±9.1	53.8°±11.0	66°±11.8	54.8°±6.7	49.2°±13.1	0.0769
Interpillar bend angle	73.9°±6.5	73.5°±6.7	66.4°±9.2	70.8°±4.5	76.4°±5.1	0.0619

All linear values are in centimeters

were more in type I C.P on both side, superior (right side -1.7±2.4 cms and left side 3.0±0.3 cms) and inferior process (right side 2.9±0.4 cms and left side 2.9±0.2 cms). This findings were significant for superior pillar on both side p-value 0.03 and 0.01.

The mean thickness of superior and inferior pillar of CP 0.65±0.2 cms and 0.8±0.24 cms, respectively. Thickness of both pillars in all types were almost same with no significant values.

Angular measurements of CP: (Table 2 and 3):

- Angulation of the superior pillar: Mean angle of superior pillar with reference to glenoid cavity in axial plane (Fig. 4) was 134°±9.2 and 131°±8.0 on right and left side respectively. Highest angle was seen in type V CP (134°±9.1 and 133°±9.7 respectively on each side) and lowest was seen in type III CP (125°± and 127°±10.1 respectively on each side). These findings were non-significant.
- Angulations of the inferior pillar:
    - **In sagittal plane:** (Fig. 2) Mean angles were 129°±7.8 and 127°±8.0 on right and left side respectively. No significant variations were observed in any of types of CP
    - **In coronal plane:** (Fig. 3) Mean angles were 135°±11.8 and 139°.4±11.8 on right and left side respectively. Highest angle was seen in type IV CP (142°±7.4 and 145.3°±5.3 respectively on each side) and lowest in type V CP (127.7°±12.2 and 129°±15.11 respectively on each side). This finding was highly significant on both sides (p value- 0.0004 and 0.008)
    - **In axial plane:** (Fig. 4) Mean angles were 54°±3.1 and 56.14°± on right and left side respectively. Highest angles was seen in type III CP (66°±11.8) and lowest in type V CP (49.2°±13.1) on the right side. Left side angulations were almost same in all types of CP

Mean of triplane angles of superior pillar in all above mentioned planes (55°, 128° and 136°) can be utilized for calculating optimal tilt of screw

Table 4: Results of studies on CP by various researchers

				Angles	I.P			
Ahors	Length	Width	Thickness	S.P axial plane	Axial	Saggital	Coronal	Bend angle
Fathi *et al.*[10]	S.P: I: 43.32±1.54 C: 42.47±1.02 M: 39.19±1.38 I.P: I: 15.94±1.33 C: 15.26±1.18 M: 14.79±0.88	S.P: I:13.63±1.09 C:13.17±0.51 M:13.02±1.32 I.P: I:25.48±1.5 C:23.90±0.76 M:22.82±0.78	S.P I:11.47±0.62 C:9.08±0.58 M:8.58±1.03	-	-	-		
Carlos *et al.*[2]		-	-	93.6°	-	49.7°	-	144°
Imma *et al.*[12]	S.P. 19.99±1.9 I.P. 18.96±3.7	11.63±2.12 13.84±1.76	-	-	-	-	-	-
Lo *et al.*[6]	S.P. 15.9±2.2	22.7±4.5	10.4±1.5					
Rajan *et al.*[12]	Right:40.70 Left: 40.74	13.05 13.57	7.20 7.65	-	-	-	-	-
Bhatia *et al.*[7]	S.P. 41.7±4.7 I.P. 31.1±2.8	14.2±2.1 16.6±2.1	8.4±1.5 9.9±2	146±7°.6	51.2±8°.3	126.1±9°.6	134±5°.5	84.9°±7.3

during surgical procedures of CP (internal fixation). Both mentioned angulations i.e., superior pillar angle and screw tilt angle should be same

- **Interprocess/bend angle:** Mean angles were 70.7°+8.4 and 73.3°±6.7 on right and left side respectively. Highest angles was seen in type V CP (76.4°±5.1 and 76.6°±7.8 respectively on each side) and lowest in type III CP (66.4°±9.3) and type IV CP (69.7°±14.7) respectively on each side. No significant variations were obtained in each type of C.P

All linear values are in milli-meters. S.P: Superior pillar, I.P: Inferior pillar, I: Indian, C-Chinese, M-Malaysian.

DISCUSSION

Two important purposes are, it acts as a medium by which the clavicle is attached to the scapula and secondly along with the acromion and coraco-acromial ligament it constructs the arch above the glenoid cavity. It also serves as a point of attachment for certain muscles. Its most important function appears to be the provision of a strong hold for the ligaments connecting it with the clavicle and in assisting in abduction of the arm[9] (Table 4).

In our study coracoid process most common type found was Type II 53% and least common was type III 5.5%. Zhang *et al.*[4] found type I and III were most frequent. Our study in in contradiction with their study which could be due to racial differences.

Length of the superior pillar in our study is mean 36.5+3.4 (34-39 mm) significant on both sides similar to study done by Bhatia *et al.*[7] This measurement provides information about maximum harvestable length of CP in procedures like coracoid transfer and construction surgeries with allograft[6].

Inferior pillar of CP is significantly longest in type V on both sides and lowest in type IV and III on right and left side respectively. our findings are lesser than observation of Bhatia *et al.*[7] Assesment of measurements of screws in surgical procedure of internal fixation can be done from this data. Measurement of pillars and the screw measurements should be equal. Table 3 shows observations by various researchers, gender and racial differences were noted by Fathi *et al.*[10] Our results match with the Indian population results of them.

Width of both process of pillars were more in Type I on both sides. Thickness of both pillars in all types of C.P were same. Our results match with findings of Bhatia *et al.*[7] but they are not significant as observed in the study done by them, where all linear measurements were significant and gender difference were also found significant. Zhang *et al.*[4] observed some linear measurements significant. the reason could be our study lack in gender differences in measurements of CP. Wider and thicker pillars require more drilling and larger thread diameter screws. therefore, according to size of different types of CP one can determine the size of the internal fixation hardware. In our study type I was widest in both the processes.

During anterior shoulder instability surgical treatment i.e. osteotomy size of exact graft is found out by calculating length from coracoid tip till 2 mm behind the midpoint of superior pillar of C.P which is the attachment point of coracoclavicular ligament. This part is described as safety margin of C.P by Dolan *et al.*[11].

Carlos *et al.*[2] confirmed in their study that like acromion process, coracoid process can also influence the coracoglenoid angle, the angle which is reduced in the Rotator cuff tear and in coracoid impingement syndrome. According to Gumina *et al.*[8] parameters of CP have influence on width of coraco humeral distance i.e. shorter is the distance leading to low values of coraco glenoid angle and coracoid overlap, which are the predisposing factors for coracohumeral impingement syndrome.

Angulations of CP is not only important in causing above mentioned diseases but also help radiologist in finding out angulations of radiographic beams and position of the patients and orthopedician in deciding angulations of screws during internal fixation procedures[6]. Beam of radiations pass at the centre of CP and radiographic plate is kept parallel to plane in which we are observing scapula. Radiograhic beam angle should be perpendicular to the plane of CP.

Mean angulation of inferior pillar in saggital plane is 128. We can calculate angle of beam of rays by subracting with the 180, so we get 180-128 = 52, 52 cranial aligns the beam perpendicular to CP in saggital plane giving maximum visibilty. Similarly for axial plane, mean angulation of superior pillar in axial plane is 133.2. So, angle of beam of rays would be 180-133.2 = 46.8, 46.8 lateral tilt of the beam aligns it perpendicular to the mean axial plane angulation of CP.

Inferior pillar angulation in coronal plane, type 5 is least than other types 2, 3 and 4 similar to the observation by Zhang *et al.*[3] Surgeries requiring drilling with this type of coracoid process where the risk of iatrogenic fracture is common surgeons have to be very careful. Other angular observations of each type of C.P was not significant[6].

Interpillar angulation in our study highest values were observed in Type V and least on type IV and III CP on either side, in contrast to Zhang *et al.*[4] they found Highest in Type IV and least in type V CP. This difference is ascribed to the race. According to Carlos this angle is 144° which is more than our mean angle, this difference in studies could be due to their study done on radiological studies and they have methodology of measuring the angle is different as they have included different axis. Coracoid bend angle influences the coracoglenoid space. This space configuration of type 1 is associated with severe narrowing of space which is an important risk factors for development of subcoracoid impingement syndrome[4].

Variations in morphology of C.P affect the ligamentous attachment making its more prone for diseases of CP like coracoid, sub coracoid impingement syndrome and rotator cuff syndrome. Lucid understanding of dimensions and effect of angulation of CP in sub coracoid space may help in management of this conditions.

Our study lacks in finding out gender, age and racial differences. Since our study is on dry scapulae, not cadaveric study we could not find out maximum harvestable length from tip of coracoid process to the attachment of coracoclavicular ligament. Our study did not include coracoglenoid angle and coracoid overlap[13].

CONCLUSION

Type 2 CP is most prevalent type and length of superior pillar was largest in type I and inferior pillar in type 5 of CP. Both pillars were widest in type I C.P on both sides. Angulation of inferior pillar in coronal plane in Type 4 was largest and Type 5 CP was least on both sides. Other linear and angular measurements were not significant. Different types of coracoid process morphology and angulations help in finding out proneness of the diseases of CP and around it. Measurements and angulation of CP should be assessed before taking up the case for surgery to avoid unnecessary events during and after surgery. Its angulations may help surgeons in deciding size and orientation of screws and for optimum visibility of C.P by radiologist, it may help in finding out proper angulations of beams of radiations to be projected on patient's shoulders.

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