Use of the fulcrum axis improves the accuracy of true anteroposterior radiographs of the shoulder

In 100 patients the fulcrum axis which is the line connecting the anterior tip of the coracoid and the posterolateral angle of the acromion, was used to position true anteroposterior radiographs of the shoulder. This method was then compared with the conventional radiological technique in a further 100 patients.

Three orthopaedic surgeons counted the number of images without overlap between the humeral head and glenoid and calculated the amount of the glenoid surface visible in each radiograph. The analysis was repeated for intraobserver reliability. The learning curves of both techniques were studied.

The amount of free visible glenoid space was significantly higher using the fulcrum-axis method (64 vs 31) and the comparable glenoid size increased significantly (8.56 vs 6.47). Thus the accuracy of the anteroposterior radiographs of the shoulder is impaired by using this technique. The intra and interobserver reliability showed a high consistency. No learning curve was observed for either technique.

Radiographs are essential for the diagnosis of disorders of the glenohumeral joint and an anteroposterior (AP) view is taken invariably. The ‘true’ or Grashey AP view differs from the standard projection in that the patient is rotated posteriorly for approximately 45° so that the plane of the scapula rather than the frontal plane lies parallel to the cassette. The aim of this projection is to visualise the joint space without any overlapping of the humeral head and the glenoid. The visible part of the articular surface of the glenoid should be as small as possible. Ideally, the anterior and the posterior rims of the glenoid, are superimposed exactly, appearing as one single line. With this view, superoinferior subluxation of the head of the humerus, joint congruity, joint degeneration and other articular abnormalities are easily assessed.

However, despite correct positioning of the patient for a true AP view, overlapping of the head and the glenoid may result since the lack of reliance on superficial anatomical landmarks to define the orientation of the glenohumeral joint space while positioning the patient make it difficult to obtain radiographs of consistently high quality.

The anterior tip of the coracoid and the posterior angle of the acromion are two surface landmarks which are easy to identify. We have previously demonstrated in an anatomical study on cadaver shoulders that the line between the anterior tip of the coracoid and the posterolateral angle of the acromion, was closely related to the plane of the glenoid. We used an experimental radiological technique on the scapulae of 143 human cadavers to enable five independent observers to identify the fulcrum axis and the glenoid fossa. The deviation between the fulcrum axis and the plane of the fossa was 1.8°, indicating that these two planes are almost parallel. AP radiographs projected along this axis would allow for improvement in the quality of the images.

Our aim was to compare two techniques for positioning patients for obtaining true AP radiographs of the shoulder in order to verify the quality of the respective images. Those taken using the fulcrum axis were compared with those using the conventional true AP technique. We determined whether the glenohumeral joint space was continuously visible and how large the visible part of the glenoid was. The learning curves for both techniques were also analysed.

Patients and Methods
The study was performed at the Departments of Traumatology and Orthopaedic Surgery and Radiology at the Ludwig-Maximilians-University Munich, Germany between March and August 2007. The landmarks of the
The fulcrum axis and the connecting line between them were marked by a single first-year resident (BO) in orthopaedic surgery who had not received any special training in surgery of the shoulder.

Evaluation of all the radiographs was carried out at the AO Research Institute, Davos, Switzerland. Ethical approval for the study was obtained from the institutional review board.

We enrolled 200 consecutive patients who required radiological imaging of their shoulders. After clinical examination they were transferred to the radiological department. Using a single x-ray unit (Philips Optimus, Philips GmbH, Hamburg, Germany) a standard protocol for taking AP shoulder radiographs (77 KV, 10 mAS) was employed. The patients were then divided into two groups after giving informed consent.

**Group I (conventional group).** This included 100 consecutive patients, 55 men and 45 women with a mean age of 52.4 years (21 to 91). Their clinical diagnosis was bruising of the shoulder in 42, fractures in 28, impingement in 17, a rotator-cuff tear in 9 and instability in 4. A conventional true AP radiograph was taken while standing upright. Using a goniometer, the patients were rotated 45° posteriorly so that the plane of the scapula was parallel to the x-ray cassette. The x-ray beam was centred on the anterior tip of the coracoid while the distance between the x-ray source and the cassette was 105 cm. The beam was directed perpendicularly to the cassette with 10° of caudal tilt.

**Group II (fulcrum group).** This included a further 100 consecutive patients. There were 47 men and 53 women with a mean age of 57.1 years (22 to 84). The clinical diagnosis was a shoulder bruise in 37, fracture in 35, impingement in 21 and a rotator-cuff tear in 7. A modified true AP radiograph was taken using the fulcrum-axis technique while standing upright. The anterior tip of the coracoid and the posterolateral angle of the acromion were marked on the surface of the body. A flexible ruler was used to mark the shortest distance between these two points to define the fulcrum axis (Fig. 1a). A 90° angle marker was temporarily fixed to the x-ray cassette and used to rotate the patients posteriorly until the fulcrum axis and the right angle were parallel (Fig. 1b). The x-ray beam was centred on the tip of the coracoid while the distance between the x-ray source and the cassette was 105 cm. The beam was directed perpendicularly to the cassette with 10° of caudal tilt.

**Assessment of the radiographs.** Three independent orthopaedic surgeons (VB, CK, PB) with special training in shoulder surgery analysed all the films to determine whether the glenohumeral joint space was continuous with no overlapping of the humeral head and the glenoid (Fig. 2). A digital analysing system (AxioVision; version 4.5 Carl Zeiss Imaging Solutions GmbH, München, Germany), was used by all observers to mark the visible area of the glenoid on each radiograph of the glenoid and to connect the most cranial and the most caudal points of the glenoid; the glenoid height, as measured in pixels (Fig. 2). Using the digital automatic analysing system Zeiss KS 400 (Carl Zeiss), the maximum width of the marked glenoid surface, measured in pixels, was measured at 90° to the evaluated height. The ratio between the glenoid height and the largest

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**Fig. 1a** Photographs showing a) the fulcrum axis which is the line connecting the anterior tip of the coracoid and the posterolateral angle of the acromion marked on the surface of the body for the true anteroposterior radiograph and b) posterior rotation of the patient using a 90° angle, temporarily fixed on the x-ray cassette until the fulcrum axis and the right angle are parallel.
glenoid width was determined for each radiograph to calculate the comparable glenoid size as follows:

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\text{Comparable glenoid size} = \frac{\text{Glenoid height}}{\text{Largest glenoid width}}
\]

The glenoid width should be as small as possible and the comparable glenoid size as high as possible. The glenoid height has been used in previous studies to establish comparability between true AP radiographs.\(^{11}\)

In order to analyse the intra- and interobserver reliability, all the measurements were performed twice by each observer with a minimum time interval of eight weeks.

The learning curve for both techniques was assessed. Regression analyses were performed using the chronology of the comparable glenoid size results of each group. The slope of the particular regression line was used to estimate the dimension of the learning curve.

Radiographs of patients with dislocation of the shoulder, replacement, arthrodesis or advanced arthritis of the glenohumeral joint were excluded from the study. In all patients an additional outlet view of the glenohumeral joint was carried out and, if necessary, CT scans were obtained to identify dislocation.

If the quality of the radiographs was inadequate for assessment of bony overlapping between the humeral head and the glenoid the films were repeated. The repeat rate for both techniques was evaluated.

**Statistical analysis.** The chi-squared test was used to compare the results of the two techniques in determining whether a continuous joint space could be identified. A p-value ≤ 0.05 was considered to be significant. The kappa coefficient was used to evaluate the intra- and interobserver reliability. The Mann-Whitney rank-sum test was used to compare the comparable glenoid size and the repeat rate of the two techniques. A p-value ≤ 0.05 was considered to be significant. The Spearman rank-order correlation coefficient was used to evaluate the intra- and interobserver reliability. In order to analyse the learning curve a chronology of the comparable glenoid size was established for both techniques and linear regression analysis was performed.

**Results**

In group I (conventional), observer 1 identified 32 images without any overlapping of the humeral head and the glenoid in the first analysis and 30 in the second. Observer 2 noted 34 on the first analysis and 33 on the second while observer 3 found 30 on the first analysis and 27 on the second (Fig. 3).

In group II (fulcrum), observer 1 found 63 images with a continuous joint space in the first analysis and 64 in the second. Observer 2 noted 34 on the first analysis and 33 on the second while observer 3 found 30 on the first analysis and 27 on the second (Fig. 3).

In group II (fulcrum), observer 1 found 63 images with a continuous joint space in the first analysis and 64 in the second. Observer 2 observed 63 in his first analysis and 62 in the second and observer 3 found 65 in his first analysis and 68 on the second (Fig. 3).

Using the chi-squared test significant differences were found between each first and each second analysis of all observers in both groups (Fig. 3). Evaluation of the intra-observer reliability of the conventional group resulted in a kappa coefficient of 0.92 and of the interobserver reliability of 0.86. In the fulcrum group the kappa coefficient was
0.94 for the intraobserver reliability and 0.86 for the interobserver reliability. On average the number of continuously visible joint spaces was significantly increased from 31 with the conventional technique to 64 using the fulcrum method.

The comparable glenoid size was evaluated for each image and the mean calculated for each analysis of each observer. The overall comparable glenoid size for the conventional technique was 6.47 and for the fulcrum technique 8.56 including the first and second analysis of each observer. The difference between the overall results of these two groups was significant (Mann-Whitney rank-sum test; \( p < 0.001 \)).

Using the comparable glenoid size with both techniques linear regression analyses were performed to evaluate the learning curves. The resulting linear equation (\( y = mx + b \)) for the conventional technique was \( y = 0.0027x + 6.33 \) and for the fulcrum technique \( y = -0.0055x + 8.87 \). No relevant slope (\( m \)) could be found for the learning curves of both techniques. Both learning curves appeared to be almost horizontal.

The repeat rate for the conventional technique was 21% while that for the fulcrum technique was 9%. The difference between the rates of the two groups was significant (Mann-Whitney rank-sum test, \( p < 0.01 \)).

### Discussion

In our study we have shown that positioning of the patient according to the fulcrum axis gives a significantly better true AP radiograph of the shoulder compared with the conventional position. The landmarks can be found easily.

Standard radiography remains important and should be performed in any patient with pain and dysfunction in the shoulder which require imaging. Compared with CT, radiography has a lower exposure to radiation, and higher availability.

Numerous authors have recommended at least two different views of the glenohumeral joint, but even then posterior dislocation of the joint may be missed in between 60% and 79% of cases and the mean interval from injury to diagnosis is one year. However, the diagnosis of
a glenohumeral dislocation should be made using the con-
ventional true AP view if this demonstrates overlapping of
the humeral head and the glenoid. The rarity of this injury could be a reason for the high rate of missed cases.
In our study overlapping of the humeral head and the
glenoid was found in approximately 70% of all cases using
the conventional technique. Using the fulcrum technique
the number of films showing continuously visible joint
spaces more than doubled.

True AP radiographs are used to measure the acromio-
humeral distance for the evaluation of the rotator cuff and
are the standard method for the diagnosis and classifi-
cation of glenohumeral arthritis. Both techniques dem-
strated a noticeable variation in the height and width of
the glenoid. However, the visible part of the glenoid decreased significantly when using the fulcrum technique.

Regression analysis is a common method of describing the dimension of a learning curve. For both techniques the learning curve appeared to be horizontal. The conventional technique has been used for many years in our clinic and this accounts for the flat learning curve. Although the fulcrum axis was marked on the body by a first-year resi-
dent in orthopaedic surgery without special training in shoulder surgery, this technique was so simple that no learning curve could be detected and the results were con-
stant from the beginning of the observations.

The tip of the coracoid and the posterior angle of the acro-
mion are superficial surface landmarks, which can easily be
found. The line connecting these landmarks is the fulcrum axis. Since this line and the plane of the glenoid fossa are approximately parallel, the former can be used for the posi-
tioning of the patient while performing a true AP radiograph.
This technique results in a higher number of continuously visible joint spaces and decreases the visible glenoid area. It may be helpful when carrying out intra-articular injections.

Supplementary material
A further opinion by Mr R. Hackney is available
with the electronic version of this article on our web-
site at www.ibjs.org.uk

No benefits in any form have been received or will be received from a commer-
cial party related directly or indirectly to the subject of this article.

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