Original article

Scapulo-humeral arthrodesis using a pedicled scapular pillar graft following resection of the proximal humerus

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ABSTRACT

Background: Scapulo-humeral arthrodesis (SHA) is a proven reconstruction method in patients with proximal humerus malignancies requiring resection of the shoulder abduction apparatus (rotator cuff and deltoid muscles) or its nerve supply. Standard practice consists in using a pedicled fibular flap. We use instead a pediculated autologous bone graft harvested from the ipsilateral scapular pillar.

Hypothesis: The objective of this study was to assess functional outcomes and radiological healing after SHA using a pedicled scapular pillar graft.

Materials and methods: We retrospectively reviewed the charts of the 12 patients managed at a single center by a single surgeon between 1994 and 2011. SHA was performed using a vascularised ipsilateral scapular pillar graft after proximal humerus resection to treat a bone malignancy. The graft was harvested from the ipsilateral scapular pillar, pedicled on the circumflex scapular artery, fitted into the remaining proximal humerus, and secured to the glenoid using screws. A humerus–scapular spine plate was added to stabilize the arthrodesis. Radiographic results were assessed on standard radiographs obtained at last follow-up. Functional outcomes were evaluated using the MusculoSkeletalTumour Society (MSTS) score and Toronto Extremity Salvage Score (TESS).

Results: After a mean follow-up of 4.9 years, 87.5% of SHA junctions were healed, mean MSTS score was 71%, and mean TESS score was 70%.

Discussion: The outcomes in our patients were similar to those reported after SHA using a pedicled fibular flap. However, our technique does not require microsurgery. It is simple, reproducible, and effective. Its indications of choice are intra- or extra-articular resection of the proximal humerus including the attachments of the rotator cuff and deltoid muscle tendons or the nerves supplying these muscles.

Level of evidence: Level IV (retrospective study).

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1. Introduction

Extensive en-bloc surgical resection is the standard of care in patients with sarcoma at any skeletal site [1–3]. At the proximal humerus, this procedure impairs shoulder and upper limb function. Reconstruction methods have been developed to restore acceptable shoulder function with no pain or construct instability over time. These methods include shoulder arthrodesis, prosthetic joint replacement, and humeral suspension to the clavicle. Pritsch et al. [4] reported unsatisfactory cosmetic and functional outcomes after humeral suspension compared to other reconstruction techniques. Prosthetic joint replacement alone [5–7] or combined with an allograft [8,9] provides good outcomes when the shoulder abductor muscles are intact [6,10–12] but exposes the patient to the complications inherent in shoulder replacement surgery, namely, infection, loosening, dislocation and instability. After rotator cuff resection, reverse shoulder arthroplasty is effective [13,14] but requires an intact deltoid muscle [15]. Scapulo-humeral arthrodesis [SHA] is an alternative to reverse shoulder arthroplasty [16,17] in patients requiring resection of the rotator cuff, deltoid, or axillary nerve. SHA avoids the complications associated with replacement surgery and is associated with high levels of patient satisfaction [18,19]. However, SHA requires the implantation of a bone graft, which may be a free or pedicled autologous graft or a frozen allograft. Pedicled grafts may provide higher healing rates while being less vulnerable to infection.

We use a pedicled bone graft harvested from the ipsilateral scapular pillar for SHA after resection of proximal humerus malignancies. The objective of this study was to assess functional outcomes and radiological healing in patients managed using this technique. To this end, we analysed the technical modalities,
limitations, clinical outcomes, and radiological outcomes in 12 patients managed at our centre by a single surgeon.

2. Materials and methods

We conducted a retrospective study of patients managed at our centre by a single surgeon.

2.1. Patients

We identified 12 patients, 4 women and 8 men, who underwent resection of the proximal humerus between 1994 and 2011. The reason for the bone resection was osteosarcoma in 6 patients, chondrosarcoma in 4 patients [including one with a dedifferentiated tumour], and Ewing’s sarcoma in one patient. The remaining patient required SHA after failure of total shoulder arthroplasty used to treat avascular necrosis of the humeral head complicating anti-phospholipid syndrome. Mean age at diagnosis was 35.6 years [range, 16–72 years] and mean follow-up after SHA was 4.9 years [range, 0.5–18 years].

2.2. Method

Proximal humerus resection was intra-articular in 7 patients, extra-articular in 4 patients, and performed after removal of a shoulder prosthesis in one patient. Mean humeral length removed was 11.6 cm [range, 6–15 cm]. All patients required resection of the rotator cuff muscle attachments and of either part of the deltoïd muscle or the axillary nerve supplying this muscle. SHA was achieved using a pedicled bone graft harvested from the ipsilateral scapular pillar. In addition, free autologous bone grafts were implanted in all patients; they consisted of iliac crest corticocancellous bone in 3 patients, non-vascularised free fibular grafts in 5 patients, tibial struts in 3 patients, and a coracoid process graft in 1 patient.

2.3. Operative technique

The patient was positioned in lateral decubitus with the upper body unsupported to allow 30° of forwards and backwards torso mobilisation.

The proximal humerus was resected through a distally extended deltopectoral approach with removal of the biopsy track. En bloc resection of the lesion was performed routinely and required removal of the rotator cuff; part of the deltoïd muscle; and attachments of the pectoralis major, subscapularis, and teres major muscles. The humerus was cut distally at the site determined during preoperative planning. The muscles of the posterior aspect of the humerus were released and the radial nerve left intact. Resection was intra- or extra-articular as determined during preoperative planning.

The second step of the procedure consisted in harvesting the bone graft. A posterior curvilinear approach along the scapular spine was extended distally along the lateral edge of the scapula. The posterior deltoïd was lifted, the humeral attachments of the teres major and minor muscles were cut, and the circumflex scapular pedicle was identified. This pedicle emerges under the teres minor muscle and provides the blood supply to the scapular pillar. The circumflex artery arises anterior to the scapula as a branch of the subscapular artery, which originates by division of the axillary artery. The circumflex scapular pedicle is located on average 2.9 cm under the lower lip of the glenoid cavity and 4.6 cm under the circumflex notch at the base of the coracoid process [20]. The pedicled graft was prepared via the posterior approach to the scapula by cutting the bony strut and releasing the latissimus dorsi muscle.

Mobilisation of this osteo-muscular block released the thoraco-dorsal pedicle without requiring specific control of the circumflex scapular artery. The latissimus dorsi flap was isolated by releasing the axillary border of the scapula and identifying its pedicle, the thoraco-dorsal artery. The latissimus dorsi has an attachment to the tip of the scapula in about 85% of cases. The scapular pillar and latissimus dorsi thus shared a pedicle (the subscapular artery), which supplied the circumflex scapular artery to the scapular pillar and the thoraco-dorsal artery to the latissimus dorsi (Fig. 1).

The scapular pillar was cut using an oscillating saw, over a width of 2 cm, from the base of the glenoid cavity to the tip of the scapula. At the glenoid cavity, the cut was made at a 45° angle to ensure a perfect fit with the recipient bone. This method produced a composite osteo-muscular graft vascularised by the subscapular artery [vascularised latissimus dorsi plus vascularised scapular pillar].

SHA was the third stage of the procedure. After freshening of the glenoid and humeral stump, the osteo-muscular flap was tipped anteriorly into the tissue defect. The distal end of the pillar was cut in a V shape that fit into the humeral stump. The supraspinatus fossa was then released to receive a plate previously angled at 110°. Fixation of the plate was with three bicortical self-tapping screws inserted into the spine of the scapula and three screws into the humeral shaft. The graft was secured to the glenoid using one or two cortical screws measuring 3.5 mm in diameter. An effective means of improving construct stability was to insert one or two screws along the axis of the scapular pillar and into the base of the coracoid process. A structural autologous bone graft was then added; it consisted of iliac crest bone, a free fibular graft, or a tibial crest strut (Fig. 2). Autologous cancellous bone chips were grafted onto the junctions. Finally, the latissimus dorsi flap was positioned in order to cover the fixation material and to restore a rounded shoulder contour (Fig. 3). The wound was closed and the shoulder immobilised in an abduction splint for 12 weeks.

2.4. Assessment methods

We evaluated both the quality of bone healing and the functional outcomes. During the last follow-up visit, the surgeon assessed bone healing on antero-posterior and lateral standard radiographs of the shoulder and humerus. Healing of the junctions (proximal and distal) was recorded as present or absent.
Function was assessed using the MusculoSkeletalTumor Society [MSTS] score [21], the Toronto Extremity Salvage Score [TESS] [22], and return to work. These outcome measures were obtained in all survivors at last follow-up. TESS values were not available for the 5 patients who died during follow-up.

2.5. Statistical analysis

Statistical analyses were performed using SPSS software (IBM, Chicago, IL, USA).

3. Results

Resection with tumour-free margins classified R0 according to the Fédération Nationale des Centres de Lutte Contre le Cancer (FNCLCC) classification were achieved in all patients [23]. During follow-up, 5 patients died of their malignancies, after a mean of 25 months [9–35 months]. Follow-up in the 7 survivors ranged from 6 to 144 months. A local recurrence 11 years after the SHA procedure required trans-scapular amputation in one patient.

Healing of both bone graft junctions occurred in 9 [75%] of the 12 patients and healing of one junction in 3 patients; thus, 21 [87.5%] of 24 junctions were healed at last follow-up (Fig. 4). Non-union of a single junction was noted in 3 patients [12.5% of all junctions]: the distal junction failed to heal in 2 patients and the proximal junction in one patient. In the 2 patients with distal junction non-union, a free fibular graft had been used in addition to the pedicled scapular pillar graft. Surgical revision with decortication, implantation of a cortico-cancellous iliac bone graft, and arthrodesis plate exchange failed in both patients. Chronic septic non-union with graft necrosis developed in one of these patients, who declined further surgery. The other patient had non-union with no pain until his death from metastatic disease. In the patient with proximal junction non-union, the pedicled scapular pillar graft had been combined with a coracoid process graft and cortical-cancellous iliac crest graft. This patient died before undergoing revision surgery, from lung metastases of her bone malignancy. Finally, one patient with a tibial fracture at a distance from the tibial strut donor site was treated with locked intra-medullary nailing.

The mean MSTS score was 71% [range, 63%–80%]. The lowest value [63%] was in the patient with non-union who declined surgical revision. The mean TESS value was 70% [range, 50%–81%] (Fig. 5). After 1 year of follow-up, the clinical results were unchanged and no patient had experienced complications or secondary deterioration. All survivors had returned to work.

4. Discussion

Use of a pedicled scapular graft for SHA provided satisfactory radiological and functional outcomes, with non-union of only 12.5% of junctions and a mean MSTS score of 71%. Only two published studies evaluating this technique are available [24,25]. The results were comparable to ours, with non-union rates of 2/14 and 1/11, compared to 3/11 in our study, and a mean MSTS score value of 75%. These data establish the reliability and reproducibility of the pedicled scapular graft technique for SHA.

The key factor in choosing the reconstruction strategy after proximal humerus resection is the status of the shoulder abduction.
apparatus. When the rotary cuff and deltoid muscle are intact, anatomic shoulder replacement surgery produces good functional outcomes, with MSTS scores of 76% [7,24]. Thus, shoulder replacement seems superior over other reconstruction techniques in this situation. In contrast, when the shoulder abduction apparatus or its nerve supply [axillary nerve] must be partly or completely removed, anatomic shoulder replacement is not feasible. The earliest conservative technique described for this situation is the Tikhoff-Linberg procedure, which consists in en-bloc proximal humeral inter-scapulo-thoracic resection and can be improved by upper limb suspension to the clavicle or chest wall [26]. Alternatives are the implantation of specific prostheses (massive or reversed) and SHA. De Wilde et al. reported a mean Constant’s score of 74% after rotator cuff resection and reverse shoulder prosthesis reconstruction [13]. Although appealing, this option is contraindicated when the deltoid muscle or its nerve supply requires resection. Kassab et al. [10] reported that the only valid reconstruction techniques after deltoid muscle and rotator cuff resection were SHA and a massive humeral prosthesis. The massive humeral prosthesis rapidly restores shoulder function without a cumbersome operative procedure requiring prolonged immobilisation. As with all prostheses, the massive humeral prosthesis is associated with complications including infection, dislocation, loosening, and uncertainty about the prosthesis survival time. SHA produces good construct stability over time with functional outcomes that compare favourably to those obtained using other techniques. Thus, the functional scores are similar to those seen after massive humeral prosthesis implantation [75%] [7,24]. We therefore believe that SHA should be considered in patients requiring extensive abductor apparatus resection, particularly when the deltoid muscle and axillary nerve must be removed [10,27].

In patients selected for SHA, a number of graft sources can be used. Rühmann et al. [28] reported a 15% non-union rate after SHA using any technique. According to the literature, the use of a pedicled fibular graft is standard practice [18,19,27,29–34]. However, this graft is associated with donor-site morbidity and requires a surgeon who has extensive experience with microsurgical anastomoses. Viehweger et al. [18] reported 2 cases of non-union among 13 patients managed with proximal humeral resection for malignancies and SHA with a pedicled fibular graft. The mean MSTS score was 88%, in keeping with the 75% mean MSTS score reported by Kassab et al. [10]. These results are very similar to ours. Pedicled fibular graft reconstruction carries a lower risk of infection that does the use of non-vascularised allografts [31]. However, pedicled fibular graft SHA has not been proven superior over our technique and has the major drawback of raising substantial technical challenges. More specifically, the need for microsurgical anastomoses induces a risk of vascular failure. A frozen allogeneic graft can be used, but this technique is associated with high infection and fracture rates [35]. O’Connor et al. obtained satisfactory healing rates by combining a frozen allogeneic graft with a pedicled fibular autograft [36]. Shimizu et al. [37] advocated the use of frozen autografts combined with a pedicled muscle flap. Tsukushi et al. [38] used an inverted autologous clavicular graft and obtained a mean MSTS score of 73%. Extra-corpooreal irradiation of the resection specimen followed by re-implantation has been suggested [39] and ensures a perfect fit between the recipient site and the graft. We have no experience with either of these two techniques, which are rarely used in France.

Thus, the main advantage of our technique is that vascularised bone is provided to the operative site without requiring vascular micro-anastomoses. This vascularised bone improves healing and decreases the risk of infection [31] without exposing the patient to the complications associated with microsurgery such as technique challenges, pedicle thrombosis, and graft loss due to avascular necrosis. Removal of the scapular pillar has no impact on function.

The main limitation of this technique is the size of the graft [24]. When the humeral resection is longer than 15 cm, the scapular pillar is too short and does not have the required shape. In general, the scapular pillar is adequate for defects of 12 cm in length and can serve in resections of up to 15 cm, as the 3-cm decrease in humeral length seen in this situation has no adverse cosmetic or functional impact. When the humeral resection is longer than 15 cm, we use a massive humeral prosthesis.

Although the muscular component of the osteo-muscular graft undergoes involution over time, it minimises the severe cosmetic disfigurement caused by proximal humeral resection.

### 5. Conclusion

The use of a pedicled scapular pillar graft for proximal humerus reconstruction after bone malignancy resection allows arthrodesis with a vascularised osteo-musculo-cutaneous graft and provides similar results to those of other techniques in terms of bone healing and patient satisfaction. This simple and reproducible technique is most useful in patients who require intra- or extra-articular resection of the proximal humerus with removal of the rotator cuff tendon attachments, deltoid muscle, or nerve supply to the deltoid muscle.

### Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

### References


