Structural Manubrium Autograft in Cervical Fusion for Patients With Cervical Tuberculosis: A Preliminary Study

Shuang Xu
Affiliated Hospital of Southwest Medical University

QING WANG (WQSPINE2004@163.com)
Affiliated Hospital of Southwest Medical University

YI LING XIONG
Affiliated Hospital of Southwest Medical University

GAOJU WANG
Affiliated Hospital of Southwest Medical University

JIN YANG
Affiliated Hospital of Southwest Medical University

SHUAI ZHANG
Affiliated Hospital of Southwest Medical University

Research Article

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Abstract

Background The purpose of this study was to evaluate the efficacy and safety of structural manubrium autografts in the surgical treatment of cervical spinal tuberculosis.

Methods From January 2015 and December 2018, 10 patients with lower cervical spine tuberculosis (C4-C7) underwent anterior debridement, interbody fusion with structural manubrium autograft, and anterior or posterior instrumentation. The medical records and radiographic findings of the patients were reviewed.

Results The surgery duration was 198.5 min and blood loss was 355.0 mL. The average preoperative kyphosis angle was $16.3 \pm 8.2^\circ$ and returned to $-2.1 \pm 2.8^\circ$ two weeks postoperatively ($P < 0.05$), reaching $-1.4 \pm 2.5^\circ$ at final follow-up ($P < 0.05$ vs. preoperative). The average preoperative visual analog scale score of neck pain was $4.1 \pm 1.1$, which decreased to $1.5 \pm 0.8$ one week after the surgery ($P < 0.05$) and to $0.7 \pm 0.5$ at final follow-up. The ESR and CRP gradually decreased postoperatively, becoming normal at final follow-up. Bony fusion was achieved in all patients by 6 months after surgery. Neurological outcomes were improved by 1–2 grades in most patients. There were no postoperative complications associated with the donor site, and there was no recurrence of tuberculosis in any patient.

Conclusion Structural bone obtained from the manubrium is safe, providing a viable alternative to cervical fusion for patients with cervical spine tuberculosis. It confers the advantages of autograft fusion without the complications associated with donor site morbidities.

Background

Cervical spine tuberculosis accounts for 3-5% of spinal tuberculosis [1-2]. Although anti-tuberculosis chemotherapy and improved nutrition have resulted in excellent functional outcomes in some patients, those patients with severe kyphosis, developing neurological deficit, or therapeutically refractory disease require surgical intervention [3-4]. Anterior debridement, decompression, fusion, and instrumentation is a commonly performed procedure for the treatment of lower cervical spine tuberculosis. However, anterior column stability should be reconstructed by bone grafting because of the large bone defect left after anterior radical debridement. Multiple techniques for structural grafting have been reported in the literature, such as iliac bone autograft, vascularized fibular graft, allograft, or titanium mesh cage [5-9]. Autologous iliac bone graft is still regarded as the “gold standard” for its superior osteoinductive and osteoconductive properties, lower risk of disease transmission, and fewer rejection reactions than allograft or synthetic materials. However, the high incidence of donor site morbidities remains a major concern [7]. To preserve the advantages of autogenous grafts and minimize the donor site morbidities, two studies used cancellous bone obtained from the sternum, achieving satisfactory fusion and fewer donor-site complications [8-9]. Here, we describe a method using structural bone obtained from manubrium for the treatment of lower cervical spine tuberculosis and evaluate the clinical results.

Methods

The general information

A total of 10 patients with cervical tuberculosis were included in this study between January 2015 and December 2018. All patients underwent anterior or combined anterior and posterior surgery in our hospital. The clinical data of the patients were retrospectively reviewed. There were five males and five females; their average age at admission was 49.5 years (range, 32–67 years). The diagnosis of cervical tuberculosis was based on the clinical symptoms, laboratory findings (such as anemia, hypoproteinemia, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP)), and images, including cervical X-ray films, computed tomography (CT) and magnetic resonance imaging (MRI). All of the patients presented with continuous symptoms, such as weakness, night sweats, neck pain and stiffness, local tenderness, and lower fever with weight loss. The patients were confirmed as having cervical tuberculosis by postoperative histopathologic examination. The indications for
surgery were spinal instability, severe and/or progressive kyphosis, neurological deficit, and large paraspinal abscess. All the patients provided written informed consent for the use and publication of data for research purposes.

**Preoperative management**

All patients in the study were clinically diagnosed with cervical spine tuberculosis. They were treated with the HREZ chemotherapy regimen for at least two weeks before surgery according to the literatures\(^3\-^4\). The surgery was carried out when ESR and CRP were significantly decreased (ESR < 40 mm/h) and tuberculosis toxicity symptoms were obviously improved following chemotherapy.

**Surgical procedure**

All operations were performed by one senior surgeon in our institute. Anterior debridement, bone graft, and instrumentation were performed in eight patients, while combined anterior debridement, bone graft, and posterior pedicle screw internal fixation were performed in two patients.

The anterior surgery was divided into three steps. The first step was radical debridement of cervical tuberculosis. Patients were placed in a supine position under general endotracheal anesthesia, and the Smith-Robinson anterolateral approach was used. After routine exposure, the necrotic material within the disc and the vertebral bodies were removed using curettes and pituitary forceps. Gradual distraction was carried out using a Caspar retractor between adjacent normal vertebrae to correct the prior kyphosis. The paravertebral and intraspinal abscess was then identified and drained. Adequate debridement of all infected materials was performed. After measuring the height of the anterior gap, the wound was repeatedly washed and then covered with wet gauze.

The second step of the surgery was the harvesting of structural manubrium autograft. A transverse 3-cm incision was made directly over the manubrium, approximately 2 cm caudal to the sternal notch. Dissection was carried down through the subcutaneous tissue to the periosteum. The anterior aspect of the manubrium was exposed to the medial limits of the sternoclavicular joints. A narrow groove with the shape of the bone opening was made on the surface of the manubrium using piezosurgery, which was limited by the sternoclavicular joints laterally, and 0.5 cm above the sternal angle cephalically and below the suprasternal notch (Fig 1). Afterward, the osteotomy was deepened to the retrosternal soft tissue, which was not affected by the vibrations of the cutting device. During the procedure, the bone was cut by carefully moving the insert back and forth with little pressure. When the inner cortex of the bone was passed and a loss of resistance was felt, the blade of the instrument was moved to a second position to complete the perimeter of the bone window. After that, the bone flap was lifted slowly away as a whole while separating the retrosternal periosteum using a periosteal detacher. Hemostasis was then carefully performed by bipolar electrocoagulation. The defect of the manubrium was reconstructed with gelatin sponge and remaining morselized bone. Finally, a drainage tube was placed, and the incision was closed in layers.

The third step was bone grafting and fixation. The trimmed sternum block was placed in the gap to reconstruct the anterior defect, and a locking plate-screw system of appropriate length was used to achieve anterior cervical fixation. For patients who underwent combined posterior and anterior surgery, posterior fixation was performed first, and anterior fixation was not required. After hemostasis and washing were performed, a deep drainage tube was placed, and the incision was closed in layers.

**Postoperative management**

The drainage tube pulled out postoperatively when the volume of drainage was less than 30 mL/24 h. Patients were allowed to ambulate with the support of a neck collar 3-5 days after surgery, which was used for 12 weeks. Anti-tuberculosis chemotherapy was continued for three months postoperatively as the same as the preoperative regimen, followed by a regimen of isoniazid, rifampicin, and ethambutol for another 9-12 months\(^5\).

**Follow-ups**
The first follow-up visit occurred one month after surgery, then at three-month intervals for the rest of the year and six-month intervals thereafter. During each follow-up, ESR, CRP, and liver and kidney function were checked. Plain films and/or CT scans were performed to investigate the bony fusion. Clinical and radiological evidence of successful fusion was defined as the absence of local pain and tenderness over the site of fusion, absence of abnormal motion, loss of correction and instrumentation failure, and the presence of trabecular bone bridging between the grafts and the vertebrae. Neurological function and neck pain were evaluated by the American Spinal Injury Association (ASIA) Impairment Scale and the visual analog scale (VAS) score, respectively.

**Statistical analysis**

All analyses were performed using SPSS Version 19.0 (Statistical Software for Social Sciences, Chicago, IL, USA). The significance of differences between Cobb angles and VAS scores at different point of time were assessed by paired-samples t-tests. Values of \( P < 0.05 \) are considered to indicate statistical significance.

**Results**

The duration of patient follow-up averaged 25.8 ± 7.1 months (range, 15–36 months). The mean surgical duration was 198.5 ± 66.0 min, and the mean estimated blood loss volume was 355.0 ± 238.5 mL. The mean preoperative ESR and CRP values were 61.4 ± 19.5 mm/h and 39.8 ± 12.0 mg/l, respectively, which decreased to 26.8 ± 6.2 mm/h and 10.6 ± 4.1 mg/l four weeks after the surgery; both differences between pre- and postoperative values were statistically significant (\( P < 0.05 \)). Three months later, both ESR and CRP had returned to normal. Patients with ASIA of grade C/D improved by 1–2 grades at the final follow-up (Table 1). All patients’ neck pain was relieved at the final follow-up. The average preoperative VAS score of neck pain was 4.1 ± 1.1, which significantly decreased to 1.5 ± 0.8 one week after the surgery (\( P < 0.05 \)) and 0.7 ± 0.5 at the last follow-up (\( P < 0.05 \) vs. preoperative). The kyphotic Cobb angles improved from 16.3 ± 8.2° preoperatively to -2.1 ± 2.8° postoperatively (\( P < 0.05 \)). During the last follow-up, the mean kyphosis Cobb angle was -1.4 ± 2.5 (\( P < 0.05 \) vs. preoperative). All patients presented with evidence of successful interbody bony fusion at the 3-6 months follow-up visit(Fig 2, Fig 3). There was no wound infection, no neurologic deterioration, and no breaking or loosening of the implant during the follow-up period. Chronic pain at the manubrium donor site was not observed. The bone defect scope of the manubrium was significantly reduced, and donor site fracture was not observed by 3-D CT.

**Discussion**

For the surgical treatment of cervical tuberculosis, the main purposes are complete debridement, decompression, kyphosis correction, and maintenance of spinal stability. Cervical spinal tuberculosis principally invades the spinal anterior column, and the anterior approach for debridement, spinal cord decompression, bone fusion, and internal fixation is the most common operative method. Hassan[2] reported the clinical results of anterior debridement, bone grafting, and instrumentation in 16 patients with lower cervical tuberculosis with kyphotic deformity.All patients presented with bone graft fusion, without internal fixation failure at 2 years of follow-up. Wu et al. [5] reported the outcomes of 17 patients with lower cervical spine tuberculosis who underwent anterior debridement, decompression, bone grafting and plate fixation, and all patients achieved bone fusion at the final follow-up. Although the treatment of cervical tuberculosis by anterior approach achieved good clinical efficacy according to literature, it is well known that if anterior cervical fusion involved more than 3 vertebras, both proximal and distal screws will suffer greater stress and are thus more likely to loosen [10]. Some authors [5-6,11] recommend that these patients undergo a combined anterior and posterior surgery. We also believe that combined anterior and posterior surgery may provide better correction of the deformity and prevent breakage or loosening of the screws. In our study, eight patients underwent anterior surgery, and two patients with more than three damaged vertebrae underwent a combined anterior and posterior procedure.

Because anterior radical debridement results in large intervertebral gap, reconstruction of the anterior spinal column is necessary. Many structural graft techniques have been used to recover cervical spine stability, such as autogenous iliac graft
or rib graft, fibular allograft, and artificial materials. The iliac crest remains the most frequently used site for bone-graft harvest because it provides an osteoconductive, osteoinductive, and osteogenic substrate for filling bone voids and augmenting fracture-healing. He et al. reported the outcome of 25 patients with lower cervical spine tuberculosis who underwent anterior debridement, decompression, structural iliac autograft, and instrumentation. Follow-up radiography showed that solid fusion was achieved in all patients with an average fusion period of 6.8 months. Although iliac grafts can achieve a good fusion rate, donor site complications must not be ignored. Myeroff et al. reported that complications associated with the harvest of autogenous iliac bone grafts occur in 10-49% of patients. The most common complication is pain at the donor site, followed by nerve injury, hematoma, infection, and donor site fracture.

The use of autografts obtained from the sternum for facial and oral reconstruction has previously been documented to be safe and effective in humans. Recently, there were some reports on the manubrium as a donor site for cervical spinal fusion. In 2007, Peelle et al. reported the results from 10 patients in whom the sternum was used as a source of autograft for anterior cervical disectomy and fusion (ACDF). All patients obtained satisfactory fusion within 4-6 months. In 2010, Sangala et al. reported a similar method of harvesting the sternal graft and presented long-term clinical outcomes of using sternal autografts for ACDF. They maintain that the manubrium provides a viable alternative to iliac crest grafting and has the advantages of autograft fusion without the complications associated with iliac crest graft harvesting. In these studies, the manubrium bone was used as a cancellous bone combined with an interbody cage for ACDF surgery. However, there have been no reports on harvesting of a structural autograft from the manubrium for bone graft.

In our previous imaging study, we showed that the mean height of the manubrium was 50.5 mm for males and 43.8 mm for females; the mean thickness was 10.4 mm in males and 9.4 mm in females; and the average breadth at the upper border is 22.3 mm for males and 19.4 mm for females. We recognized that it was possible to obtain a structural bone from the manubrium. In this study, the structure of the manubrium was first carefully evaluated with three-dimensional computed tomography (3D-CT), then we cut open a bone window on the center of the manubrium using piezosurgery and harvested a structural autograft for cervical fusion. All patients achieved bone fusion in 3-6 months. We believe there are two principal advantages to the structural manubrium autograft. First, it is performed in the same surgical area as anterior cervical surgery, and there is less additional procedure of disinfecting towel. Second, it has an excellent fusion rate similar to that of the iliac graft, while avoiding the complications common to the iliac crest and artificial materials. The disadvantage is that manubrium has a limited amount of bone available, which meet the needs of reconstruction of bone defect after one vertebral resection.

The posterior of the manubrium is near important structures, such as the pleura and the great vessels, and there was some concern that these structures might be damaged during bone harvesting. However, according to our experience, there is a loose space between the retrosternal periosteum and mediastinal tissue, and using piezosurgery to harvest bone allowed us to avoid injury to posterior sternal soft tissue. In our cases, no injury of the pleura or mediastinal vessels has occurred. In addition, there was no chronic pain at the donor site or sternoclavicular joint and no weakness of the upper limb during follow-up. Finally, 3D-CT showed that the defect area of the manubrium became smaller over time, and no fractures occurred at the donor site.

If planning a structural manubrium graft, it is necessary to assess the manubrium structure by 3D-CT to exclude a small or malformed manubrium and to measure the amount of manubrium that can be removed. If the manubrium is small or malformed, or if the patient has severe osteoporosis, iliac bone or artificial materials are preferred. In addition, because the anterior sternal wound is prone to scar formation, especially in those with scar diathesis, it is not recommended to obtain bone from the manubrium in young female patients nor other patients who are particularly concerned about cosmetic effects.

Although satisfactory outcomes were obtained in this study, we recognize several limitations. First, the sample size of this study is small and there was no control group, which made it impossible to obtain a high strength of evidence regarding the
superiority of using structural manubrium autograft in cervical tuberculosis. Second, the long-term complications of harvesting structural bone from manubrium are not yet clear, and thus long-term follow-up is needed.

**Conclusions**

This preliminary study indicates that structural bone obtained from the manubrium is safe, providing a viable alternative to cervical fusion for patients with cervical spine tuberculosis. This bone grafting procedure, which goes without harvesting bone from the iliac crest and using artificial materials, not only avoids donor site morbidities, but also brings about favorable clinical outcomes. Just further study with a large number of patients and longer follow-up will be necessary.

**Declarations**

**Ethics approval and consent to participate**

Ethical approval from the Ethics Committee of the affiliated Hospital of Southwest Medical University was obtained for this study. Each author certifies that all investigations were conducted in conformity with ethical principles. Written informed consent was obtained from all patients included in the study.

**Consent for publication**

All patients signed informed consent to publish their personal details in this article.

**Availability of data and materials**

The datasets supporting the conclusions of this article are included within the article. The raw data can be requested from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ contributions**

study design,QW,SX; data collection,GJQ,JY; data analysis,SZ; writing original draft preparation, SX; prepared figures,YLX. All authors have read and approved the final manuscript, and ensure that this is the case.

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**Tables**

**Table 1 Summary of clinical data obtained in the 10 patients with cervical spinal tuberculosis**
| No. | Sex | Age (y) | Neurologic status | Affected segments | ASF level | Approach | Blood loss(ml) | Operative time (min) | Kyphosis (°) | Preop. | Postop. | FFU |
|-----|-----|--------|--------------------|-------------------|-----------|----------|----------------|----------------------|--------------|--------|---------|-----|
| 1   | M   | 33     | D                  | C5-7              | C5-7      | A+P      | 400            | 300                  | 8            | 0      | 0       |     |
| 2   | M   | 30     | D                  | C5-6              | C5-7      | A        | 400            | 270                  | 10           | -6     | -5      |     |
| 3   | F   | 56     | D                  | C5-6              | C4-7      | A        | 300            | 110                  | 17           | -2     | 0       |     |
| 4   | M   | 41     | C                  | C6-7              | C5-7      | A        | 200            | 200                  | 5            | -3     | -2      |     |
| 5   | M   | 43     | C                  | C4-5              | C3-5      | A        | 200            | 180                  | 10           | -5     | -3      |     |
| 6   | F   | 70     | C                  | C5-6              | C5-7      | A        | 300            | 190                  | 22           | 0      | 0       |     |
| 7   | F   | 67     | D                  | C6-7              | C5-7      | A        | 200            | 175                  | 15           | -3     | -2      |     |
| 8   | F   | 51     | D                  | C6-7              | C5-7      | A        | 250            | 145                  | 20           | -3     | -3      |     |
| 9   | M   | 46     | E                  | C5-6              | C4-6      | A        | 300            | 130                  | 29           | -3     | -3      |     |
| 10  | F   | 35     | E                  | C3-5              | C3-5      | A+P      | 1000           | 285                  | 27           | 4      | 4       |     |

preop., preoperative; FFU, final follow-up; ASF, anterior spinal fusion; postop., postoperative; A, anterior approach; P, posterior approach

**Figures**

**Figure 1**

a Structural bone was harvesting from manubrium using piezosurgery b-c Postoperative 3D-CT show the scope of defect of the manubrium, which become smaller one year after operation
Figure 2

A 35-year-old female patient with cervical spine tuberculosis (C3-5) a-c Preoperative radiography, CT and MRI showed destruction of C3–5 vertebrae with retropharyngeal abscess and epidural abscess d Postoperative midsagittal reconstructed computed tomography (CT) scan demonstrated anterior debridement, structural manubrium bone grafting and posterior internal fixation e-f Radiography taken at 4 months of follow-up showed bone fusion at the interface.
Figure 3

A 46-year-old male patient with cervical spine tuberculosis C5-6. a-c Preoperative radiography, CT and MRI showed significant cervical kyphosis, C5-C6 vertebral body destruction, epidural abscess formation and spinal cord compression. d Postoperative CT showed cervical kyphosis improved after anterior debridement, structural bone grafting and anterior plate fixation. e Radiography taken at 3 months of follow-up showed bony fusion was obtained at the graft-host junction. f CT scan at 12 months of follow-up showed and correction of kyphosis was maintained, and implants were in good position.