

Management of scaphoid nonunion with avascular necrosis using 1,2 intercompartmental supraretinacular arterial bone graft

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Abstract

Background: 1,2 ICSRA, introduced by Aidembery *et al.*, is a well-established technique, with up to 100% union rate among different studies. The purpose of our study was to evaluate the outcome of scaphoid nonunion undergoing 1,2 ICSRA bone graft in Iran.

Materials and Methods: All participants who presented sequentially over a period of 24 months between 2010 and 2013 with nonunion scaphoid fracture with AVN in proximal pole were included in the study. Anteroposterior and lateral view plain radiographs of carpal bones were obtained for diagnosis of nonunion, and a diagnosis of avascular necrosis was made by MRI of the scaphoid. Subjects underwent 1,2 ICSRA bone graft surgery. Patients were assessed based on radiographs and the Mayo Wrist Score (MWS) questionnaire on before and after surgery. Data were analyzed using SPSS ver. 18 by paired *t* test.

Results: Overall, 16 patients (100% male) were included in the study. Mean age of subjects was 27.50 ± 5.86 (18 to 38). Mean Mayo score was 36.63 ± 8.92 and 83.75 ± 9.22 before and 6 month after surgery, respectively, and the difference was statistically significant ($P < 0.001$). After 8 weeks, 10 (62.5%) had union, and after 12 weeks, all subjects had union. Nine (56.25%) of our patients had excellent functional outcome, 5 (31.25%) had good and 2 (12.5%) had satisfactory functional outcome.

Conclusion: 1,2 ICSRA is a proper pedicle of vascularized bone graft due to the ease of visibility and dissection. The functional results and union rates were satisfactory in our study.

Key Words: Avascular necrosis, 1,2 ICSRA, non-union, scaphoid

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INTRODUCTION

The most common fracture among carpal bones accounting for 60% of all carpal fractures is the scaphoid fracture and must always be included in the differential diagnosis for wrist sprain.^[1-3]

Although most of scaphoid fractures will unite in satisfactory position, rate of nonunion is still

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dramatically high, bearing in mind its adverse effects on individual's life. Nonunion in proximal pole seen in 5-15% of scaphoid fractures, even in treated fractures. Thus, early diagnosis and proper treatment of scaphoid fractures as soon as possible is highly important to prevent scaphoid nonunion advanced collapse (SNAC) complications. Scaphoid non-unions can progress to carpal collapse and degenerative arthritis, causing personal and economic costs, and decrease in quality of life.^[1,2]

Avascular necrosis is seen in approximately 30-40% of scaphoid fractures, mostly seen among proximal pole fractures.^[4] The retrograde blood supply to the proximal pole of scaphoid bone makes it susceptible to a higher nonunion rate and avascular necrosis (AVN) after fractures. Thus, the preference of vascularized bone graft for the treatment of non-union, especially with associated AVN, is justified.^[2]

Bone graft with or without fixation, vascularized bone graft, electrical stimulation, and different salvage procedures such as excision or replacement of one portion or all of scaphoid, proximal row carpectomy, and arthrodesis are the different surgical methods for treatment of scaphoid nonunion.^[5]

Determining the type of surgery and its effects on carpal function is an important step in treatment of scaphoid nonunion. Non-surgical methods include electrical stimulation and casting; however, in all cases of scaphoid nonunion, surgical procedures are strongly recommended, and non-surgical methods are only reserved for subjects in whom surgery is contraindicated.^[2,3] In all cases with apparent carpal arthritis, surgery is necessary.^[2]

Several surgical procedures have been developed for treatment of nonunion, including vascularized and non-vascularized bone graft, with or without internal fixation.^[2] Among them, vascularized bone graft has recently gained the greatest popularity due to the higher union rate.^[3,6] Moreover, in the presence of proximal pole AVN, only vascularized bone graft can ascertain revascularization of the ischemic bone portion, resulting in higher union rate and shorter time to union.^[4,6]

Different vascularized bone grafts from the distal radius have been used for years, including pronator quadratus, the volar carpal artery, and more recently, the 1,2 intercompartmental supraretinacular artery (1,2 ICSRA).^[3,4,6-8]

1,2 ICSRA, introduced by Aidembery *et al.*, is a well-established technique, with up to 100% union rate among different studies.^[4,6,9-11] However, this

method has not been previously evaluated in Iran, and there are a few studies in the world. The purpose of our study was to evaluate the outcome of scaphoid nonunion undergoing 1,2 ICSRA with vascularized graft in Iran.

MATERIALS AND METHODS

All participants who presented sequentially to the outpatient educational clinics in Isfahan, Iran over a period of 24 months between 2010 and 2013 with nonunion scaphoid fracture with AVN in proximal pole were included in the study. Written consent was obtained from all subjects.

Subjects with underlying diseases such as liver disorders, heart disorders, renal disorders, or other contraindications for surgery were excluded from the study. We also excluded those with chronic disorders affecting quality of life, or subjects with a history of surgery on carpal bones or those with osteoarthritis in carpal bones. Likewise, subjects using systemic glucocorticoids, or drugs affecting bone density such as thyroid hormones, glucocorticoids, methotrexate, heparin, warfarin, anti-epileptic agents, alendronate, calcitonin, raloxifen, vitamin D were not included in the study.

A detailed history was taken from subjects, and physical examination was performed to determine existence of any systemic disorder. Anteroposterior and lateral view plain radiographs of carpal bones were obtained for diagnosis of nonunion, and a diagnosis of avascular necrosis was made if MRI of the scaphoid revealed low signal intensity on T1-weighted images combined with high signal or ISO intensity on T2-weighted images. AVN was also confirmed during surgery by no bleeding from the proximal pole of the scaphoid. After confirmation of AVN, patients were included in the study. Laboratory tests including CBC diff, liver function tests, and renal function tests were performed before surgery.

Subjects were included in surgery schedule for 1,2 ICSRA bone graft surgery with dorsoradial approach. Blood perfusion of proximal pole of scaphoid was assessed by white color and no bleeding from proximal pole after deflating the tourniquet. Fibrosis and avascular bone portion were removed from site of injury, and bone graft was harvested with a sleeve of periosteum containing 1,2 ICSRA and transformed to the scaphoid recipient site. Fixation was performed with Herbert screw or pin, and removable thumb spica was used for stability

for 4 weeks. Subjects were not allowed to work for 6 months after surgery.

Anteroposterior and lateral plain radiographs were obtained 4, 8, 12, and 24 weeks after surgery to evaluate healing and union at fracture site. Union was determined by formation of trabecular bridging of scaphoid bone portions.

Patients were also assessed based on the Mayo Wrist Score (MWS) questionnaire before and after surgery. The questionnaire evaluates pain intensity, functional status, range of motion, and grip strength. Scores are recoded into 4 groups: Excellent (90-100), Good (80-90), Satisfactory (60-80), Poor (<60).

Data was analyzed using SPSS ver. 18 by paired *t* test. *P* value < 0.05 was considered statically significant.

Excellent (90-100), Good (80-90), Satisfactory (60-80), Poor (<60).

RESULTS

Overall, 16 patients (100% male) were included in the study. Mean age of subjects was 27.50 ± 5.86 ranging from 18 to 38 [Table 1].

Mean Mayo score was 36.63 ± 8.92 and 83.75 ± 9.22 before and 6 month after surgery, respectively, and the difference was statistically significant (*P* < 0.001) [Table 2].

Four weeks after surgery, none of the subjects had union, but after 8 weeks, 10 (62.5%) had union, and after 12 weeks, all subjects had union.

Nine (56.25%) of our patients had excellent functional outcome (Mayo wrist score 90-100), 5 (31.25%) had

good (80-90), and 2 (12.5%) had satisfactory functional outcome (Mayo wrist score 60-80).

DISCUSSION

In this research, we studied nonunion of the scaphoid with AVN, which is a difficult problem to treat. Despite the improved recognition and diagnosis of scaphoid fractures and the advent of the well-established treatment options, the rate of healing is still not optimum.

The conventional Russe onlay bone graft is considered as the treatment of choice for the patients with scaphoid nonunion.^[1,2] Chen *et al.* retrospectively reviewed 39 patients with scaphoid nonunion treated using the “sandwich” method that consisted of a wedge corticocancellous strut graft and numerous cancellous bone chips. Divergent Kirschner wires were used for fixation of reduction. All 26 patients had follow up periods of 3 to 6 years, and the nonunion scaphoids of all patients had united within 4 months of their operations. The functional results were either good or excellent.^[1]

However, the “sandwich” method is relatively contraindicated for patients in whom the proximal pole of the scaphoid is totally avascular.^[1-3] Green reported a prospective study of patients with nonunion of the scaphoid treated using the Russe bone grafting method. Twenty-four of 26 patients (92%) with good vascularity in the proximal pole achieved solid union, but none of the 5 patients in whom the proximal pole was totally avascular achieved successful union. He concluded that the absence of intra-operative punctate bleeding points on the cancellous surface indicated avascularity of the proximal pole and may explain the failure of bone grafting procedures. When pre-operation suggestions of severe AVN of the proximal pole are confirmed intraoperatively, a vascularized pedicle bone graft should be strongly considered.^[1,4,8] This allows for the import of osteogenic progenitors to enhance the healing potential of the fracture, together with its inherent blood supply to improve graft survival rather than depend on the unreliable vasculature of the scaphoid.^[2] This offers a shorter period of immobilization and a higher union rate.^[1,2,4]

Table 1: Patient demographics

| Demographic | No. (%) |
|---------------------|-----------------------|
| Male gender | 16 (100.0) |
| Mean age (years) | 27.50±5.86 (18 to 38) |
| Avascular necrosis | 16 (100.0) |
| Associated injuries | 0 (0.0) |

Table 2: Mayo wrist score

| Section 1 pain intensity | Section 2-functional status | Section 3 (choose either a or b) | | Section 4 grip strength % of normal |
|--------------------------|--------------------------------|---------------------------------------|----------------------------------|-------------------------------------|
| No pain | Returned to regular employment | 3a-range of motion (% of normal side) | 3b-If only injured hand examined | 100 |
| Mild occasional | Restricted employment | 100 | Greater than 120 degrees | 75-100 |
| Moderate, tolerable | Able to work, but unemployed | 75-99 | 90-120 degrees | 50-75 |
| Severe to intolerable | Unable to work because of pain | 50-74 | 60-90 degrees | 25-50 |
| | | 0-24 | 30-60 degrees | 0-25 |

Many different methods have been reported for obtaining vascularized grafts. Chacha reported a bone graft with a vascular pedicle from the pronator quadratus.^[5,7,8] The disadvantages of the pedicle were that the arc was too short and the muscle bulk limited adequate visualization of the reduction. Contraction of the muscular pedicle sometimes caused loss of reduction.^[1,6]

Guimberteau and Panconi reported a vascularized cortical and cancellous bone graft from the ulna.^[9] The vascular pedicle was obtained from the ulnar artery. The disadvantages of this procedure included a long operating time and the need to reconstruct the ulnar artery with a venous graft. In addition, the procedure was associated with a risk of fracture of the ulna.

Brunelli *et al.* described a bone graft that was obtained from the distal part of the second metacarpal.^[1] The vascularity of the graft was derived from the deep artery of the first web space on the lateral aspect of the metacarpal. Mathoulin and Brunelli reported that it was difficult to obtain the graft and to position it within the scaphoid.^[1,9]

Gabl *et al.* described free vascular bone grafts from the iliac crest.^[7] Kazuteru *et al.* described free vascular bone grafts harvested from the femoral supracondyle.^[1,7] The results of their studies were all good, but the procedures needed microscopic vessel anastomosis and required long operative times.

Zaidenberg *et al.* presented a vascularized bone graft from the radial aspect of the distal part of the radius.^[8-12] The vascular pedicle was based on the recurrent branch of the radial artery. Rather than directly lying on periosteum as originally described, the vessel was lying superficially on the dorsal surface of the extensor retinaculum between the first and second compartments. Because of its location, the vessel was named the 1, 2 intercompartmental supraretinacular arteries (1, 2 ICSRA). It is easily visible after retraction of the skin and subcutaneous tissues. The arc of rotation was sufficient to reach the scaphoid bone area.^[8,9] Uerpaiojkit *et al.* also reported a vascularized bone graft from the dorsoradial aspect of the distal radius used with internal fixation to treat nonunion of the scaphoid in 10 patients who had not received any previous surgical treatment. Associated AVN was observed in 5 patients. Postoperatively, pain was relieved, and union was achieved in all cases. Range of motion, grip strength, and pinch strength were also satisfactorily restored.^[1,11]

The 1,2 ICSRA is superficial to the retinaculum and runs directly into the bony tubercle. It is a proper pedicle of

vascularized bone graft due to the ease of visibility and dissection. We concluded that vascularized bone graft with 1, 2 ICSRA is useful to repair a nonunion with AVN of a scaphoid fracture. In our series, we were able to achieve a union rate of 62.5% for patients with AVN and 100% for those without AVN using the 1,2 ICSRA vascularized graft. Fourteen (87.5%) of our patients had excellent and good functional outcome, which is comparable to other studies. This result was similar to the experience in other countries. The limitation of this study was the small sample size, which could have led to our inability to identify any statistically significant factors that adversely affected the outcome. In view of the variability in success rates among our surgeons and in the literature, a prospective randomized study with clearly defined patient selection criteria, surgical technique, and post-operative management comparing the 1,2 ICSRA-based vascularized bone graft with conventional iliac crest bone grafting is necessary to establish the true usefulness of pedicled distal radius-based vascularized bone grafts for scaphoid nonunions with AVN of the proximal pole.

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