Computer Tomography assessment of the fusion rate after posterior arthroscopic subtalar arthrodesis

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Abstract

Purpose The purpose of this study was to assess the fusion rate on CT examinations and to correlate clinically the functional result with the degree of bone fusion in the subtalar joint after posterior arthroscopic subtalar arthrodesis (PASTA).

Methods Fourteen cases, from 36 to 84 years old, were retrospectively followed-up for a minimum of one year (range 12–92 months). A CT scan had been systematically performed at the six-month follow-up visit. The CT scans were examined in sagittal 2-mm-thick reformatted slices, measuring the length of the joint surface and the length of the fused portion of the joint space on each image.

Results At six months, the average fusion ratio was $39 \pm 19\%$ (range 0–69%). Fusion defined by a fusion ratio superior or equal to 33% on the CT scan was observed in 11 cases. One patient had a delayed union and required a revision of fixation. One patient had a bilateral nonunion. Mean average AOFAS score improved from 51 ± 10 to 77 ± 9 at last follow-up.

Conclusion Compared to open procedures, the posterior arthroscopic fusion seems to offer a promising alternative. However, our results suggest that the fusion rate following PASTA is not as favourable as reported in previous studies. Factors such as adequate compression and stable fixation

provided by the screws together with the surgeons' experience with this demanding technique are of the utmost importance. A 33% CT fusion ratio threshold could accurately discriminate between clinical stability and instability.

Introduction

Arthrodesis has proven to be a useful surgical treatment for a severely degenerated subtalar joint. Arthroscopic subtalar arthrodesis was developed to improve open methods by using a minimally invasive technique, which theoretically preserves blood supply and reduces perioperative morbidity. Since 1994, most investigators have performed arthroscopic subtalar arthrodesis in the supine or lateral decubitus positions [9, 13, 14]. Van Dijk et al. described a posterior two-portal arthroscopic approach for the hindfoot in the prone position which provides safe access, superior visualisation of the posterior talocalcaneal facet and easy fixation of posterior screws [15]. This technique also seems to provide good clinical outcomes and a union rate similar to open techniques, but we found only six series in the literature reporting the union rate assessed on conventional X-rays after posterior subtalar arthrodesis (PASTA) [1, 2, 4, 5, 8, 12]. To our knowledge, no study has reported the percentage of bone fusion on CT after PASTA. We postulated that the fusion rate is similar to that obtained with open techniques and that a fusion rate superior to 33% is clinically correlated with a satisfactory functional outcome.

Patients

Between October 2003 and April 2010, 14 PASTA (six left hindfoot, eight right hindfoot, one bilateral) were performed

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on 13 patients (six female, seven male). The mean age at operation was 55 years (range 36–84). The indication for operation were post traumatic OA in six cases and primary OA in eight cases. Five hindfeet had previous operations, which included five open reduction, internal fixation (ORIF) and two hardware removals. The indications for surgery were pain associated with arthritis of the posterior aspect of the subtalar joint which had failed to respond to conservative treatment. All the patients had been assessed clinically and had plain radiographs and CT studies. The CT was used to assess the joint space narrowing of the three facets of the subtalar joint. Two patients had a tibiotalar arthrosis and underwent a combined arthroscopic tibiotalar arthrodesis simultaneously. One patient had a Chopart arthrosis and also underwent a combined open Chopart arthrodesis in supine position.

Operative technique

The arthroscopic procedure was performed with the patient in the prone position. The procedure was carried out under tourniquet. Arthroscopy was performed with a 30° 4.5-mm optic arthroscope through a posterior two-portal approach, as described by van Dijk et al. [15]. Through a stab incision just lateral to the Achilles tendon slightly above the tip of the malleolus, the entry for the arthroscope shaft was prepared. A common complication after arthroscopic arthrodesis is superficial nerve injury at the portal site. This complication can be avoided by careful attention to the technique of portal creation. The portal must be created by incising the skin only, spreading the subcutaneous tissue with a haemostat and then penetrating with a blunt trocar. Instruments were inserted through the medial portal at the same level as the posterolateral portal. Better access to the posterior subtalar joint can be obtained by placing the foot in dorsiflexion. The shaver was introduced through the posteromedial portal. The flexor hallucis longus tendon should be identified because it is an important landmark to prevent damage to the more medially located neurovascular bundle. Once the flexor hallucis longus tendon (FHL) was identified (Fig. 1a), the soft tissue surrounding the posterolateral tubercle was debrided with a shaver (Fig. 1b). In the case of posterior osteophyte or a voluminous posterolateral process, the bone fragment was removed with an osteotome (Fig. 1c) and then excised with grasping forceps (Fig. 1d). The initial debridement and synovectomy were performed using 4-mm resectors. Clearance of the articular surfaces was performed with a 10-mm osteotome and straight curettes (Fig. 1e and f). Stabilisation of the joint was accomplished with internal fixation via one or two 6.5-mm percutaneous cannulated screws from the non-weight-bearing portion of the calcaneal tuberosity directed to a

Fig. 1 Intraoperative views of arthroscopic subtalar arthrodesis. **a** The flexor hallucis longus tendon (FHL) is identified. **b** The soft tissue surrounding the posterolateral tubercle is debrided with a shaver. **c** In case of voluminous posterolateral process, the bone fragment is removed with an osteotome. **d** The posterolateral process is excised with grasping forceps. **e** The subtalar joint is exposed. **f** Clearance of the articular surfaces is performed with straight curettes

point 5- to 10-mm posterior to the anterior margin of the posterior facet. Care must be taken when choosing the entry point in the calcaneal tuberosity. A too medial position can lead to an “in-out-in” position of the screw, due to the concave shape of the medial aspect of the calcaneal tuberosity with potential damage to the posterior tibial pedicle. This complication can be avoided by the hand sensing the drill progressing in the bone, although placing the guide wire for the cannulated screw provides a less sensory feedback. The joint is positioned and held in 5° of hindfoot valgus. No autogenous bone graft or bone substitute is needed for this procedure. Forced dorsiflexion during screw insertion can help to provide adequate compression and to reduce the gap which is usually seen at the arthrodesis site on the intraoperative films. The skin incisions are closed and posterior splints applied. After ten days, the splint is removed, and a cast applied for the next three months. The patient is instructed to use crutches for ambulation and to avoid weight-bearing activities for the first eight weeks, with progression to weight-bearing as tolerated over the next four weeks.

Postoperative evaluation

The patients were reviewed at last follow-up with plain radiographs. The American Orthopaedic Foot and Ankle (AOFAS) [11], Angus and Cowell [3] scores were completed. A CT scan was performed at the six-month follow-up visit. The CT scan was examined in sagittal 2-mm-thick reformatted slices, measuring the length of the joint surface and the length of the fused portion of the joint space on each image (Fig. 2). The sum of the lengths of the fused segments on all slices was then divided by the sum of the lengths of the joint surfaces to calculate the fusion ratio according to the technique described by Dorsey et al. [6].

Results

Overall clinical and radiographic outcomes are shown in Table 1. The mean modified AOFAS score (maximum, 94 points) improved from 51 ± 10 points (range, 40–72 points) preoperatively to 77 ± 9 points (range, 63–93 points) at final follow-up. According to the Angus and Cowell criteria, seven of 14 feet (50%) had a good rating and seven (50%) had a fair rating. The union rate was $39 \pm 19\%$ at six months and delayed union observed on the CT scan occurred in three cases. One delayed union eventually healed and two became nonunions. The patient with a delayed union required revision of fixation. The initial screw was not adequate as it was a cortical 4.5-mm screw which could not provide compression of the posterior subtalar facet (Fig. 3a and b). The fusion rate on the six-month follow-up CT scan was 24%. It was decided to replace the screw by a 6.5-mm cannulated screw and the joint eventually fused. At seven-years follow-up, her AOFAS score was 69. The two cases of nonunion occurred in the same 41-year-old man. He is a regular smoker (20 cigarettes a day) and had not stopped

despite advice given by the surgeon. In one case (right side), an additional cause of failure was identified. The screws were not correctly positioned and could not provide adequate compression at the arthrodesis site (Fig. 3c and d). The hardware from the previous operation had not been removed and it was not possible to put the screws 5-mm posterior to the anterior margin of the posterior facet as recommended by Carro [5]. The patient still complained of bilateral heel pain and although nonunion was diagnosed on the six-month CT scan, he did not come to his follow-up visit. A bilateral nonunion was diagnosed when he was contacted for this study. At 36-months follow-up, his AOFAS score was 65 on both sides.

One patient complained of pain over the distribution of the sural nerve. Injury to the sural nerve can occur due to retraction, direct injury related with the placement of incisions, or from scarring during the recovery process. In this case, the sural nerve was not cut. He underwent neurolysis of the sural nerve 18 months after the index operation. He noticed improvement following the neurolysis but still experienced hypoesthesia in the nerve territory at the latest follow-up. Pain may be associated with the screws that are used to secure the joint. One patient needed removal of the screws due to discomfort once the bone had healed.

No other postoperative complications such as tibial posterior nerve or artery injury, synovial fistula, varus malunion, deep vein thrombosis, lateral malleolus impingement or reflex sympathetic dystrophy occurred.

Discussion

The most important finding of this study is that PASTA is a safe and reliable technique and a fusion rate superior to 33% provides pain relief and is clinically correlated with a good functional outcome. There are some advantages to prone positioning compared to lateral positioning. It allows a better assessment of the calcaneus valgus during screw insertion, and placement of the screws from the calcaneus posteriorly is convenient as intraoperative imaging by fluoroscopy from behind can be easily obtained. Six series, including a total of 54 patients, have been published using this technique [1, 2, 4, 5, 8, 12]. All the authors report a fusion rate of 100%, Amendola et al. who observed one non-union out of 11 cases [2] and Lee et al. who found one non-union out of 16 cases [12]. However, we found a surprisingly low rate of fusion in our study with a mean fusion rate of 39% which is less than that usually reported after open subtalar arthrodesis. This result is in accordance with the relatively high rate of nonunion in our series. The typical nonunion rate is in the order of 16% for the subtalar joint with conventional techniques [7]. The nonunion rate is dependent upon the patient's underlying condition, whether

Fig. 2 Measurement technique for fusion ratio performed on every sagittal slice through posterior subtalar joint. The long white arrow shows length of posterior subtalar joint; the short red arrow shows length of fused segment of joint. Note that the fixation screw is not centred in the fused portion

Table 1 Patient demographics, operative details, clinical and radiological results

Patient number	Age (years)	Initial ORIF	Combine arthrodesis	Number of screws	Fusion rate at 6 months (%)	Complication	FU (months)	AOFAS score		Angus and Cowel criteria	
								Preop	Follow-up		
1	36	No	No	1	48	Sural nerve	44	54	83	Good	
2	58	No	Chopart	1	58	No	92	40	88	Fair	
3	56	No	No	1	44	No	14	52	69	Fair	
4	84	No	No	1	24	Delayed union	90	65	69	Fair	
5	Right Left	42	Yes	No	2	5	Nonunion	54	42	65	Fair
			Yes	No	1	0	Nonunion	43	35	65	Fair
6	55	Yes	No	2	48	No	50	49	81	Good	
7	56	No	No	1	41	No	19	62	84	Good	
8	49	Yes	No	1	37	No	18	43	63	Fair	
9	80	No	Tibiotalar	1	48	No	20	51	75	Good	
10	57	No	No	1	33	No	18	72	84	Good	
11	63	No	Tibiotalar	1	47	No	16	56	81	Good	
12	53	Yes	No	1	44	No	14	42	76	Fair	
13	41	No	No	2	69	No	12	49	93	Good	

ORIF open reduction, internal fixation, FU follow-up, AOFAS American foot and ankle society

the patient smokes cigarettes, the patient's compliance with the postoperative non weight-bearing protocol, the presence of more than two millimetres of avascular bone at the arthrodesis site, and the failure of a previous subtalar arthrodesis. We related the two cases of nonunion in the same patient with the

fact that he is a smoker. Moreover, one case of nonunion and the case of delayed union can be directly attributed to technical mistakes. In one case of nonunion, the hardware had not been removed and led the surgeon to place the screws too anteriorly. Thus, the compression was not optimal and could explain the absence of healing. In the case of delayed union, the screw was not appropriate (a 4.5-mm full threaded cortical screw) and the arthrodesis eventually healed when the fixation was revised.

The authors usually attribute the high success rate for the arthroscopic approach to the subtalar joint to the ability to preserve the blood supply with the microinvasive technique. Our results suggest however that PASTA is a demanding technique which requires mastering of arthroscopic technique and a rigorous mode of fixation. In the arthroscopic procedure, autograft [1, 9], allograft or no graft at all [2, 4, 5, 8, 12] are used. In the literature, two non-unions were reported, one with an allograft [2], the other without graft [12]. Other factors such as bone vascularity, correct debridement up to subchondral bone, adequate compression provided by the screws and stable fixation may be more important than the use or the type of graft used. A systematic autologous bone graft is not necessary from our point of view, but should be considered in smokers or when screw fixation is not optimal despite the maximal compression allowed by the quality of the bone.

Jones et al. [10] were able to detect only seven of 13 hindfoot nonunions with conventional radiographs. This low sensitivity is probably due to a combination of complex postsurgical joint surface anatomy and bone overlap

Fig. 3 Failures related to technical mistakes. **a** and **b** Delayed union in an 84-year old patient. The 4.5-mm full threaded cortical screw was not sufficient to provide sufficient coaptation at the arthrodesis site. **c** and **d** Non-union in a 41-year old patient. The hardware from the previous surgery had not been removed leading to improper placement of the cannulated cancellous screws

obscuring areas of joint space radiolucency on the radiographs. The finding of persistent radiolucency crossing the entire joint space at six months combined with loosening, bending, or breakage of fixation screws are still a highly specific sign of arthrodesis nonunion but these signs are rarely present and were never found in our non-union cases. Moreover, we believe as does Dorsey [6] that a small number of asymptomatic patients can have a low percentage of bone fusion after attempted arthrodesis. We report the first study in which the results of an arthroscopic subtalar posterior arthrodesis have been studied with a CT-scan rather than plain radiography. Perhaps this is the reason why the final results regarding the fusion rate are not as good as they appear in other studies, although the functional outcome is quite similar. The patient of our series who had a bilateral nonunion reported an improvement in functional scores and was able to resume his daily activities. Thus, nonunion could be easily underdiagnosed in the subtalar joint. Jones et al. developed a CT grading system for evaluating the effect of ultrasound stimulation on bone fusion, but they had no standard of reference [10]. The authors arbitrarily defined a CT finding of nonunion as 0–33% fusion on CT, partial union as 34–66% fusion, and complete union as 67–100% fusion. Dorsey et al., in a recent CT study, confirmed that a 33% CT fusion ratio threshold could accurately discriminate between clinical stability and instability [6]. Our study confirms these findings, as we found a globally low rate of bone fusion at between 33% and 50% in the majority of clinically stable patients. Furthermore, all the patients of our series with a fusion rate inferior to 33% had a bad functional outcome and needed revision surgery.

This study has however several weaknesses. In the absence of a control group it is not possible to know whether the mini-invasive procedure has brought any additional benefit to the patients. It is a retrospective study with a short-term follow-up and the patients are a heterogeneous mix. The functional results must be interpreted with care because some patients had undergone a tibiotalar or a Chopart arthrodesis at the same time. We decided however to include these patients as the aim of the study was rather to assess the fusion rate on CT scan after PASTA than to analyse the functional result after PASTA. The patients had undergone operations by three different surgeons and the technique of fixation varied between the different patients. This is probably due to the evolution of the technique. The failures have led us to try to place two distally threaded cancellous screws when the surface of the subtalar joint allows it. It is also mandatory to remove hardware when it is present as the position of the screw is crucial in order to obtain the best compression possible at the arthrodesis site. The relatively low rate of fusion in our series could be linked with the limited experience of the surgeons with the

technique and highlights the fact that as with other minimally invasive techniques, PASTA is associated with a significant learning curve.

Conclusion

Posterior arthroscopic subtalar arthrodesis (PASTA) in the prone position through a posterior two-portal approach provides safe access of the posterior talocalcaneal facet and allows easy fixation of posterior screws. Our study confirms that it is a safe and reliable method which leads to a clinically stable union and pain relief in a majority of patients who complain of hindfoot arthritis. However, as with other minimally invasive techniques, PASTA is associated with a significant learning curve and requires a perfect surgical technique and mastering of hindfoot arthroscopy. The most frequent complication is nonunion when the fusion site fails to adequately fuse together. Persistent heel pain at six-month follow-up must lead the surgeon to perform a CT scan which is the only reliable way to differentiate stable unions from unstable unions. Our results confirm that a 33% fusion ratio threshold is relevant. This interpretation technique may help to identify patients who could benefit from additional surgical treatment.

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