0363-5465/102/3030-0581$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 30, No. 4

Long-Term Outcome of Fasciotomy with Partial Fasciectomy for Chronic Exertional Compartment Syndrome of the Lower Leg*

Drew Slimmon,† Kim Bennell,†§ PhD, Peter Brukner,†‡ MBBS, FACSP, Kay Crossley,†‡ BAppSci(physio), and Simon N. Bell,‡ MBBS, FRACS

From the †Centre for Sports Medicine Research and Education, School of Physiotherapy, Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Parkville, and ‡Olympic Park Sports Medicine Centre, Melbourne, Australia

Background: Fasciotomy with partial fasciectomy for compartment syndrome has had good short-term results, but no long-term studies have been performed.
Hypothesis: Combining a partial fasciectomy with fasciotomy for compartment syndrome relieves pain and eliminates symptoms in the long term.
Study Design: Retrospective cohort study.
Methods: A self-administered questionnaire was given to 62 patients at a mean follow-up of 51 months after surgery.
Results: Of the 50 patients who underwent a single operation, 60% (30) reported an excellent or good outcome. Average pain and pain-on-running were significantly reduced, although some subjects still reported considerable levels of pain. Fifty-eight percent (36 of 62) were exercising at a lower level than before injury and, of these, 36% (13) cited the return of their compartment syndrome or the development of a different lower leg compartment syndrome as the reason for a reduction in exercise levels. Some subjects indicated early initial improvement followed by subsequent deterioration.
Conclusion: This surgical technique reduces pain and allows the majority of patients to return to sports; however, patients should be counseled that they may not be able to return to their preinjury level of exercise or remain pain-free.

Compartment syndrome is a condition in which either exertion or trauma causes increased pressure within a musculofascial compartment, causing pain that may be associated with neurologic deficits and muscle dysfunction. It can be acute or chronic in nature. Chronic exertional compartment syndrome of the lower leg is a common exercise-related injury in young active people, particularly those involved in running sports and in military training.[4,8,23,29] If the physician fails to recognize and adequately manage this condition, it can be extremely debilitating to the patient. Although there is currently no accepted standard diagnostic procedure, a precise diagnosis of chronic exertional compartment syndrome can generally be made with a high degree of clinical suspicion, a careful history, a full physical examination, and compartment pressure testing, bone scanning, or both.[20]

The causes of chronic exertional compartment syndrome are incompletely understood, but it is widely thought that abnormal increases in intramuscular pressure during exercise impair local perfusion, thereby resulting in tissue ischemia and pain.[6,17] For this reason, surgical intervention has involved releasing the affected compartment, with only minor variations in surgical technique described in the literature. The majority of variations apply to the fasciotomy technique described in detail by Rorabeck and colleagues.[25] The use of fasciotomy or fasciectomy has been debated, with some surgeons performing a fasciotomy with a partial fasciectomy. In this technique, the involved compartment is released in the normal fashion and then a window of fascia tissue is removed to ensure that scar tissue cannot form between the split fascial ends. Although pilot data suggest that this

* Presented at the Fifth IOC World Congress, Sydney, Australia, November 1999.

§ Address correspondence and reprint requests to Kim Bennell, PhD, Centre for Sports Medicine Research and Education, School of Physiotherapy, University of Melbourne, Parkville, Vic 3010, Australia.

No author or related institution has received any financial benefit from research in this study.

technique may be effective,[5] no researchers have comprehensively evaluated the effectiveness of this technique or compared its success in different lower leg compartments.

Various surgical success rates have been reported for this condition, but these reports are questionable because of methodologic limitations. Previous outcome studies for chronic exertional compartment syndrome of the lower leg have indicated relatively high success rates for surgery in the short term[1,12,19,25–27,32]; however, information about long-term outcomes is inadequate. Furthermore, few studies have been performed by someone other than the surgeon involved, leading to potential bias in the results. The objectives of this study were to establish long-term surgical success rates for the technique of fasciotomy combined with partial fasciectomy and to compare the results in different lower leg compartments. The same experienced surgeon performed all operations to ensure a standardized approach. However, the surgeon was not involved in the follow-up study, thereby eliminating a major source of potential bias.

MATERIALS AND METHODS

Subjects

All 157 patients with a diagnosis of chronic exertional compartment syndrome (88 men and 69 women) who underwent unilateral or bilateral compartment fasciotomy with a partial fasciectomy of the lower leg by one orthopaedic surgeon (SNB) during the period from January 1992 to June 1997 were identified from the surgeon's patient files. Patients were eligible for inclusion into the study if they were between 18 and 40 years of age at the time of surgery. The upper age limit was selected to reduce the risk of confounding the results with additional age-related conditions. A compartment pressure test had been performed before the operation by a sports medicine physician and the result was positive in all patients. The diagnostic criteria used to confirm chronic exertional compartment syndrome of the lower leg were those outlined by Pedowitz and colleagues,[21] based on the following compartment pressures: before exercise, more than 15 mm Hg; 1 minute after exercise, more than 30 mm Hg; and 5 minutes after exercise, more than 20 mm Hg.

Patients were excluded from the study if they had an additional condition of the shin or calf at the time of surgery. Of the 157 patients who had undergone the procedure, 140 were eligible for the study. The remaining 17 were excluded because they did not fulfill the age criterion ($N = 14$) or because they had additional lower leg conditions ($N = 3$). Letters were sent to all 140 subjects, but only 65 could be contacted, despite considerable effort to locate them. Three of these 65 subjects chose not to participate in the study. Two stated they did not have sufficient time to complete the questionnaire, and one claimed that "none of the questions (were) relevant to (his) compartment syndrome." This resulted in a recruitment rate of 95% for contactable patients and 44% for all eligible patients. Table 1 lists the patients according to the type of surgical procedure, and information about the subjects' physical characteristics is found in Table 2.

Questionnaire

The questionnaires were completed without investigator or surgeon influence. If subjects had bilateral surgery, a separate questionnaire was completed for each leg. For those who did not wish to participate in the study, space was provided on the information cover sheet to provide reasons for that decision.

Subjects who had repeat surgery for compartment syndrome were required to complete a slightly shorter questionnaire that omitted questions related to any time after the repeat operation. Only the results of the first operation until their optimum or best response level were evaluated because comparisons between subjects who had undergone only one procedure and those who had a repeat operation would only be valid until the time of the best outcome after the first operation.

The questionnaire was based on one previously used to assess the outcome of surgery for patellar tendinopathy (jumper's knee).[10] It required subjects to outline their symptoms before the operation, at their optimum response level after the operation, and at the time of follow-up. Information was also sought regarding the duration of preoperative symptoms and the presence and duration of postoperative surgical complications. Subjects were asked to evaluate the outcome of the operation in terms of pain, return to preinjury sport, competitive sports level after the operation, and weekly exercise. They were also asked to offer their perception of the overall outcome of the operation. Readers may obtain a copy of the questionnaire from the corresponding author. The University of Melbourne Human Research Ethics Committee approved the study, and all subjects provided written informed consent.

Surgery

The same surgeon (SNB) performed all of the operations and had performed a total of more than 260 compartment decompressions before and including 1997. The technique of compartment decompression was based on that de-

TABLE 1
Number of Patients According to Surgical Procedure

Sex	Unilateral surgery	Bilateral surgery	Anterior compartment surgery only	Posterior compartment surgery only	Combined surgery
Men	4	23	7	13	7
Women	3	32	14	13	8
Total	7	55	21	26	15

TABLE 2
Patient Characteristics for the Three Surgical Groups (Means and Standard Deviations)

Characteristic	Anterior compartment surgery	Posterior compartment surgery	Combined compartment surgery
Age (years)	25.3 (5.3)	26.3 (6.6)	24.9 (7.0)
Height (cm)	170.7 (9.0)	168.6 (12.9)	174.6 (4.09)
Weight (kg)	67.9 (9.9)	68.6 (13.0)	70.8 (9.1)

scribed by Rorabeck et al.[25] but with considerable modification for both the anterior and posterior compartment decompression procedures. In particular, the surgeon thought that the success rate might be improved if a partial fasciectomy, as well as the traditional fasciotomy, was performed.[5] The technique was not significantly varied throughout the course of the study.

The technique for anterior compartment decompression involved the use of a single, 4-cm long incision over the center of the anterior compartment. The fascia over the anterior and lateral compartments was split longitudinally over its entire length. A partial fasciectomy of both compartments was then performed, with the removal of an approximately 10-cm long window of fascia. The intermuscular septum was then divided transversely.

The technique for posterior compartment decompression involved the use of a single, 10-cm long incision over the central posterior aspect of the tibia. The periosteum was stripped from the posteromedial aspect of the tibia, and an approximately 15-cm long strip of periosteum was excised. If a discrete fascia was present over the tibialis posterior muscle, the flexor digitorum muscle was mobilized bluntly from the fascia, which was then split longitudinally, and a portion was centrally excised. The remaining fascia over the flexor digitorum muscle was split longitudinally and a portion was excised. The fascia over the superficial posterior compartment was also split longitudinally, with the split extending proximally over the medial head of the gastrocnemius muscle. The fascia was then also divided transversely.

For both the anterior and posterior compartment decompressions, the wounds were closed with subcutaneous Dexon (Davis & Geck, Danbury, Connecticut), subcuticular Prolene (Ethicon, Somerville, New Jersey), and sterile adhesive strips. A firm bandage was then applied from midfoot to knee.

The patients all followed a similar postoperative rehabilitation program, usually supervised by a physical therapist. The patients remained in bed for at least 4 days with their legs elevated. During this period, dorsiflexion exercises were commenced. Most patients needed to use crutches for at least 2 weeks after the operation. After rehabilitation of 3 weeks, bicycle and pool work was begun, and the patients were permitted to start running 4 weeks after the operation.

Statistical Analysis

Data were analyzed separately for anterior, posterior, and combined operations. Nonparametric tests were used, as the data were not normally distributed. Kruskal-Wallis one-way analysis of variance was performed to compare results across the three surgical groups. Friedman tests were applied to compare results across time within each surgical group. An alpha level of $P < 0.05$ was set for these tests. If a significant difference was found, three post hoc Mann Whitney *U*-tests or Wilcoxon matched-pairs signed-rank tests were performed to locate the source of the difference. A Bonferroni correction was applied to these tests so that the alpha level became $P < 0.016$ ($P = 0.05/3$). Chi-square tests were used for comparison of categorical variables.

RESULTS

Subject Characteristics

A total of 148 compartment operations were performed on the group of 62 patients, which included 27 men and 35 women. The mean (±SD) age of the patients at the time of the operation was 25.6 (±6.2) years. The median preoperative symptom duration was 12 months, with a mean of 30 (±41.7) months and a range of 2 to 300 months. The mean length of follow-up in the study was 51 (±20) months, with a range of 24 to 107 months. Before the operation, the activities and sports performed by the patients included netball ($N = 13$), Australian Rules football ($N = 9$), track and field ($N = 8$), tennis ($N = 5$), basketball ($N = 2$), soccer ($N = 2$), and others ($N = 10$). The level of competition included 4 international, 12 national, 28 state/district, and 12 recreational. Thirteen subjects did not participate in competitive sport. There were no significant differences between the three surgical groups with respect to age, height, weight, duration of preoperative symptoms, investigations, or in the levels of sport played preoperatively ($P > 0.05$).

Subject Perception of Surgical Outcome

Overall, 60% of the patients (37 of 62) reported their surgical outcome to be excellent or good at follow-up. The percentage of satisfactory (excellent and good) compared with unsatisfactory (fair and poor) outcomes differed across the three surgical groups ($P = 0.002$). A greater proportion of subjects who underwent surgery in the anterior (65%) and posterior (75%) compartments reported a satisfactory outcome compared with those who had combined surgery (31%) (Table 3).

Pain

Before the operation, many of the patients were substantially debilitated by the condition. In the week before surgery, as many as 85% of the patients (53 of 62) were unable to run because of their compartment syndrome, and 55% (34 of 62) had to cease their aggravating activity because of pain. Fifteen percent of the subjects (9 of 62) reported that their pain severely limited or prevented them from walking, and 6% (4 of 62) reported severe limitations in activities of daily living.

TABLE 3
Number of Subjects Reporting Different Outcomes at Follow-up

Outcome	Anterior compartment surgery		Posterior compartment surgery		Combined compartment surgery	
	N	(%)	*N*	(%)	*N*	(%)
Excellent	5	(29)	12	(60)	2	(15)
Good	6	(35)	3	(15)	2	(15)
Fair	4	(24)	2	(10)	6	(46)
Poor	2	(12)	3	(15)	3	(23)
Required repeat surgery	4		6		2	

At the time of follow-up, overall average pain and worst pain were rated as less than 3 on a 10-cm visual analog scale. There was a significant difference in worst ($P < 0.0001$) and average ($P < 0.002$) pain levels when the different surgical groups were compared (Fig. 1). The patients who had anterior compartment or combined surgery reported similar levels of pain, and these levels were significantly greater than those of the patients who had posterior compartment surgery for both worst ($P < 0.0001$) and average ($P < 0.001$) pain. Pain levels reported by the patients ranged from 0 to 9 on a 10-cm visual analog scale, indicating that, whereas some patients were pain-free, others still had substantial pain more than 2 years after the operation.

Mean levels of worst pain while running, a common aggravating activity for patients with chronic exertional compartment syndrome, are shown at different time points in the three surgical groups in Table 4. One week before the operation, the mean worst pain while running was rated as more than 8 on a 10-cm visual analog scale, indicating severe pain during this activity. There was no significant difference between surgical groups at this time. Six months after the operation, all groups demonstrated similar reductions in pain (all $P < 0.0001$), with mean pain score rated between 3 and 6 on the visual

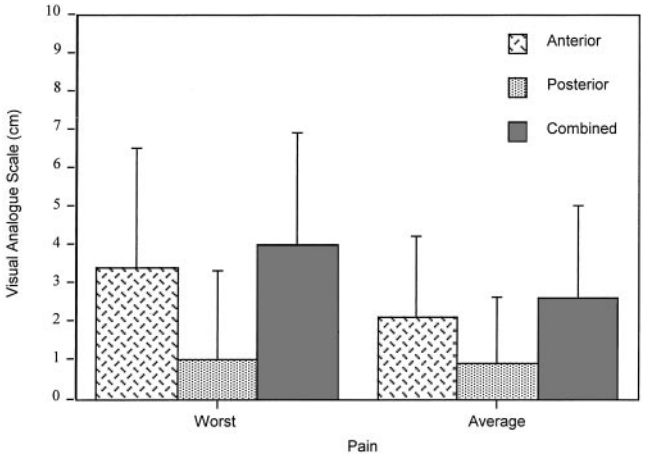

Figure 1. The worst and average pain scores at the time of follow-up for the three surgical groups. Bars show the means and standard deviations of the pain scale scores.

TABLE 4
Reports of Worst Pain with Running at Three Different Time Points in the Three Surgical Groups as Measured on a 10-cm Visual Analog Scale

Type of surgery	1 week before surgery	6 months after surgery	At follow-up
	Mean (SD)	Mean (SD)	Mean (SD)
Anterior compartment	8.2 (2.2)	4.3 (2.8)	3.4 (3.0)
Posterior compartment	8.8 (1.2)	3.2 (3.6)	1.3 (2.3)
Combined	9.1 (0.9)	5.3 (2.7)	5.1 (2.7)

analog scale. At the time of follow-up, there were no further reductions in pain in patients who had anterior compartment or combined surgery. However, the patients who had posterior compartment surgery showed a further reduction in worst pain during running ($P = 0.0004$) compared with their scores 6 months after the operation. Thus, at the time of follow-up, the posterior compartment group reported significantly less pain during running than both the anterior compartment and combined groups ($P = 0.004$ and $P < 0.0001$, respectively).

Exercise Levels

Exercise levels at the time of best outcome and at follow-up were compared with preinjury exercise levels. At the time of the best outcome, 74% of the patients (46 of 62) were exercising at the same or higher level than before their injury, but at the time of follow-up this figure had decreased to 42% (26 of 62). There was no difference between surgical groups for exercise levels at best outcome or at the time of follow-up. For subjects who were exercising at a lower level than before injury at the time of their best outcome ($N = 16$), the most common explanation for the decline was the return of their symptoms (Table 5). At the time of follow-up, 36% of the subjects who were exercising at a lower level than before injury (13 of 36) cited the return of their compartment syndrome or the development of a different compartment syndrome as the reason for a reduction in exercise levels.

Effect of Symptom Duration on Surgical Outcome

Preoperative symptom duration may have affected the success of surgery (Fig. 2). Among the group undergoing

TABLE 5
Reasons Given by Patients for Exercising at a Lower Level than Before Injury (Number and Percentage)

Explanations	Best outcome ($N = 16$)		Time of follow-up ($N = 33$)	
N (%)	*N*	(%)	*N*	(%)
Retirement for reasons unrelated to injury	4	(25)	14	(39)
Return of compartment syndrome symptoms	8	(50)	12	(33)
Different compartment syndrome	1	(6)	1	(3)
Different injury	3	(19)	6	(17)

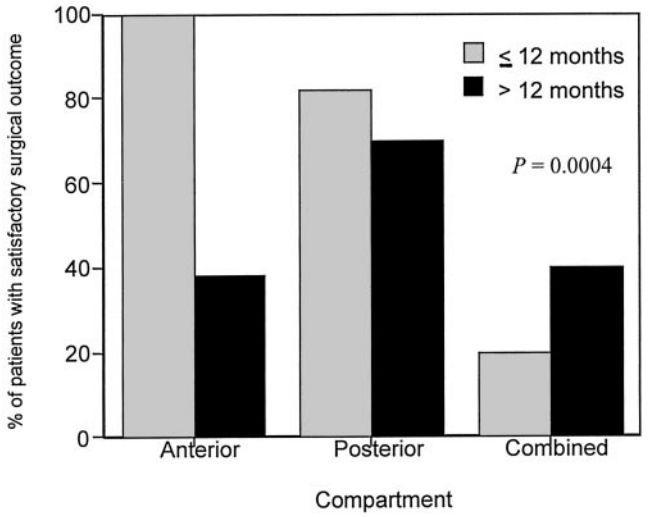

Figure 2. The percentage of patients in each surgical group reporting satisfactory surgical outcome compared with the duration of their symptoms before surgery.

anterior compartment surgery, all eight subjects reported satisfactory outcomes when surgery was performed within 12 months of the onset of symptoms ($P = 0.0004$). However, when surgery was performed after more than 12 months of symptoms, only 33% (3 of 9) reported a satisfactory outcome. Subjects in the anterior compartment surgery group who had satisfactory outcomes had a mean preoperative symptom duration of 17 months, compared with 42 months for those in the same group who had an unsatisfactory outcome ($P < 0.01$). Conversely, preoperative symptom duration was not related to outcome in patients undergoing posterior compartment or combined surgery.

Multiple Operations

Twelve patients underwent multiple sequential surgical interventions for chronic exertional compartment syndrome (11 underwent 2 operations and 1 underwent 3 operations). The average time of the second operation after the first was 23 months. This group included 4 patients who initially had anterior compartment procedures (7 legs), 6 with posterior compartment procedures (11 legs), and 2 with combined procedures (4 legs). Of this group, five patients (42%) managed to return to a similar or higher level of exercise than before injury after their initial operation, but at some stage their condition deteriorated and a subsequent operation was required.

Surgical Complications

There were few major complications arising from this operation. Among the group with posterior compartment surgery, two subjects reported postoperative clotting and another reported phlebitis, but these symptoms resolved within 4 weeks. One subject in the anterior compartment surgery group reported a wound infection that lasted for 12 months. Overall, 90% of the subjects (56 of 62) reported some form of minor postsurgical complication, with no difference across surgical groups. These included numbness (persisting on average for 100 weeks) and bruising and swelling (persisting on average for 68 weeks). Other less common minor complications included skin infections (2, persisting on average for 4.5 weeks), increased sensitivity (21, persisting on average for 96 weeks), and weakness (15, persisting on average for 40 weeks). Complications that were reported by the group who had anterior compartment surgery took longer to resolve than did those reported by the other groups.

DISCUSSION

More than 2 years after the procedure, the majority of patients with chronic exertional compartment syndrome of the lower leg treated with a fasciotomy and partial fasciectomy reported a satisfactory outcome associated with reduction in pain level and improvement in exercise level compared with those before the operation. A satisfactory outcome was more likely to be obtained as a result of surgery of the posterior compartment, regardless of symptom duration, whereas a better outcome was found for surgery of the anterior compartment if the symptom duration had been less than 12 months. However, although overall results were positive, some subjects still reported substantial pain in the long term or required a repeat procedure, particularly if the anterior compartment was involved. The pattern of recovery from the operation in some patients indicated early initial improvement followed by subsequent deterioration.

Before the operation, many subjects reported debilitating pain that interfered with or caused cessation of everyday activities. Worst pain with running was rated more than 8 on a 10-cm visual analog scale, indicating severe pain. The surgical procedure resulted in a significant reduction in pain both at 6 months after the operation and at follow-up. The operation also allowed approximately half of the subjects to return to the same or higher level of exercise as before injury, both at the time of the best outcome and at final follow-up.

However, despite favorable results in many patients, a proportion of the patients still reported substantial pain at follow-up and an inability to attain preinjury levels of activity. Some had initial improvement followed by a return of their symptoms or the development of new chronic exertional compartment syndrome of the lower leg. There are several explanations for an unsatisfactory surgical outcome in this condition. The first relates to the fact that a definitive method of diagnosing chronic exertional compartment syndrome is yet to be established. Although the diagnosis was made by using the best currently available procedures, including compartment pressure testing and a standardized protocol, it is possible that the condition was misdiagnosed or that a coexisting pathologic condition was responsible for the pain symptoms. Thus, surgical decompression would fail to address the contributing condition.

The second explanation is that, although a correct diagnosis was made, the surgical technique failed to adequately decompress the compartment(s). However, this is less likely, as the surgeon was very experienced in this particular technique. The pathophysiology and mechanism of pain production in this condition are not clear. A role for ischemia has not necessarily been supported by imaging studies,[2,3] and other hypotheses regarding the causes of pain include stimulation of intramuscular pressure receptors or release of metabolic by-products leading to stimulation of pain nerve endings.[15] If pain originates from sources other than increased pressure in the compartment, then symptoms will persist, despite successful decompression. It is also possible that, despite initial short-term surgical success, the pain recurs because of secondary delayed effects of the surgery, such as scarring or muscle damage. Furthermore, there may be an inherent predisposition to chronic exertional compartment syndrome in some patients. Whether this possible predisposition reflects an intrinsic structural defect or the persistence of risk factors such as excessive training or abnormal biomechanics is not clear.

The exercise level of subjects before the operation might have had an influence on surgical outcome, especially in terms of sporting success. A large proportion of international, national, and state/district level competitors were included in this study. The nature of more elite competition means that subjects may be less likely to return to their former level of sport, even after strict adherence to a rehabilitation program, than would those whose participation in sports was purely recreational. The elite athletes might also have had higher expectations for the surgical outcome and hence be dissatisfied if they were unable to attain their previous competitive level. In a study in which subjects were mainly military recruits or less serious athletes,[24] better outcomes may have been reported because patients had lower preinjury levels of exercise.

Despite reports of similar pain levels before surgery and at 6 months afterward by patients in all surgical groups, by the time of final follow-up, patients who had posterior compartment surgery reported further improvement and less pain than did the patients undergoing anterior compartment or combined surgery. Conversely, other studies that have used pain as an outcome measure have not reported a difference in postsurgical pain levels between patients on the basis of the involved compartment.[13,14,22,30,33] Greater relief of symptoms has also not been reported in studies of patients who had posterior compartment surgery.[5,11,27,32] However, the difference may be due to the shorter duration of follow-up in these earlier studies. A short follow-up would not necessarily detect differences between surgical groups because the results of our study suggest that these differences only become evident at some time beyond 6 months after the operation.

The finding of less pain in the group undergoing posterior compartment surgery is also surprising given the fact that the diagnosis of compartment syndrome is often less clear in these patients than in those with anterior compartment syndrome. Also, the surgical procedure is more difficult because of the deep anatomic positioning and presence of an extra fascial layer in some cases. The surgical groups were well matched as to sex, age, symptom duration, height, weight, and sporting activity; therefore, it is unlikely that these factors confounded the operative results. Thus, the reasons for differences in pain level between the groups are unclear, and the literature provides no feasible explanation for this finding.

The duration of preoperative symptoms affected the proportion of satisfactory outcomes only in the group who had anterior compartment surgery. If the operation was performed within 12 months of the onset of symptoms, all subjects reported a satisfactory surgical outcome at the time of follow-up, compared with less favorable outcomes if the operation was performed more than 12 months after the onset of symptoms. It is possible that there is a different pathologic process responsible for anterior compartment syndrome than that for the other compartments. Over a prolonged period, it is conceivable that irreversible changes occur to the muscles as a result of ischemic damage or direct pressure necrosis. By interceding with early surgery, before these irreversible changes occur, the surgeon may improve the likelihood of a successful outcome of the operation. However, comparison of blood supply in affected and in normal compartments has failed to show a difference.[2,3] Furthermore, this theory tends to be refuted by the fact that the reports of patients in the combined surgery group, whose procedure also involved the anterior compartment, did not show a similar correlation between preoperative symptom duration and satisfactory surgical outcome. No other investigators have studied the relationship between symptom duration and outcome to allow comparisons to be made.

Our success rate for posterior compartment surgery (75%) was similar to rates reported in the literature for other surgical techniques in the posterior compartment.[1,7,22,25,27,32] Although it is difficult to directly compare studies because of the different methods involved, this similarity suggests that the choice of technique need not be made on outcome but on factors such as surgeon preference. The success rate for anterior compartment surgery (65%) was well below the documented rates in the literature,[1,5,7,11,14,23–27,30–33] as was the success rate for combined surgery (31%).[26,27,33] It is possible that the higher success rates for anterior compartment and combined surgery reported in the literature may be a result of publication bias against less favorable medical research.[16,28] There is clearly a disincentive for surgeons to publish results of an operation in which the outcome proves to be somewhat unrewarding.

Our surgical procedure involved the addition of a fasciectomy to the traditional fasciotomy in an attempt to improve the results. Fasciectomy has been shown to be an effective second procedure for patients in whom "simple" decompression was not successful.[5] However, the long-term outcome appears to be no better than that reported for simple decompression. Without the results of a prospective randomized trial, it is therefore still uncertain as to whether the addition of a fasciectomy results in a better technique. The postoperative complications reported by

our patients were relatively minor, and it is unknown whether the additional fasciectomy influenced their likelihood of good results.

There were several methodologic issues in our study that warrant consideration. We had strict selection criteria and a very high level of recruitment of the patients whom we were able to contact. A potential confounding factor was the low number of eligible patients that we were able to reach. The length of follow-up meant that patients had changed residence and could not be traced, despite considerable effort to locate them. However, there is no reason to believe that the patients who could not be contacted had a different surgical outcome than did those in the study sample.

The potential influence of response bias arising from surgeon involvement in the process of outcome assessment has been well documented.[18] In only two of the previous outcome studies did researchers avoid this potential bias.[7,33] In the present study, the surgeon was not involved, and all subjects were clearly informed that the surgeon would not have access to any study data. All subjects reported their own outcome according to written criteria without investigator assistance. Thus, the data are more likely to reflect the subjects' true perceptions of outcome.

Clear outcome measures are a vital part of any surgical study, yet many reports of the outcome of compartment syndrome surgery do not clearly state whether the results reflect the best outcome after the operation or the outcome at the time of follow-up. This distinction is important because reported outcomes at follow-up may be far less favorable than those reported at the time of best outcome. Assessing outcome a few months after the operation will probably reveal that most patients have returned to participation in sport. However, sufficient follow-up time is required to fully assess outcome and recurrence rates. Consequently, our study had a minimum follow-up period of 2 years, and 75% of the patients were followed up for more than 3 years.

There are inherent limitations to retrospective studies. Subjects' preoperative and postoperative treatment could not be controlled, and reliance on subjects' recall was required for information on outcome. These limitations are not unique to this form of study design, but, despite them, valuable information can be obtained from retrospective studies.[9] Reliable descriptive studies are initially required to assess the outcome of new procedures before embarking on prospective studies. Rigorous retrospective studies provide valuable information for the formulation of hypotheses that are the basis of further prospective randomized controlled trials.

In summary, the results of this study have shown that a surgical technique involving fasciotomy with partial fasciectomy for chronic exertional compartment syndrome is generally successful in the short term but less so in the long term. Although the results of our study should be confirmed in a prospective study design, they suggest that surgeons should counsel patients with compartment syndrome who are considering surgical intervention. These patients may not necessarily be able to return to their preinjury level of sport or be free of pain in the long term. Moreover, minor postsurgical complications were revealed to be common and quite persistent, although relatively harmless. Other risks arising from compartment surgery appear to be minimal, yet the patient should be counseled about complications, particularly more serious ones such as clotting and phlebitis.

The reasons for failure of surgery and for the differences between groups with surgery of different compartments remain unclear at this stage but may involve misdiagnosis, an irreversible condition resulting from a long duration of symptoms,[11] undetermined pathologic conditions, or long-term muscle damage or re-formation of fascial adhesions caused by compartment syndrome or by invasive surgery. Further research should focus on the causes and pathophysiology of the condition so that better diagnostic procedures and treatments can be established.

ACKNOWLEDGMENTS

The authors thank Dr. Chris Bradshaw, Dr. Andrew Jowett, Dr. Paul Blackman, and Ms. Deborah Horne of the Olympic Park Sports Medicine Centre, Melbourne, and Dr. Steven Kiss of East Melbourne Radiology for their assistance with this project.

REFERENCES

1. Allen MJ, Barnes MR: Exercise pain in the lower leg: Chronic compartment syndrome and medial tibial syndrome. *J Bone Joint Surg 68B:* 818–823, 1986
2. Amendola A, Rorabeck CH, Vellett D, et al: The use of magnetic resonance imaging in exertional compartment syndromes. *Am J Sports Med 18:* 29–34, 1990
3. Balduini FC, Shenton DW, O'Connor KH, et al: Chronic exertional compartment syndrome: Correlation of compartment pressure and muscle ischemia utilizing 31P-NMR spectroscopy. *Clin Sports Med 12:* 151–165, 1993
4. Baquie P, Brukner P: Injuries presenting to an Australian Sports Medicine Centre: A 12-month study. *Clin J Sport Med 7:* 28–31, 1997
5. Bell S: Repeat compartment decompression with partial fasciectomy. *J Bone Joint Surg 68B:* 815–817, 1986
6. Black KP, Schultz TK, Cheung NL: Compartment syndromes in athletes. *Clin Sports Med 9:* 471–487, 1990
7. Bradshaw C, Blackman P, Brukner P, et al: Chronic exertional compartment syndrome in the lower leg: A comparison of treatment options and outcomes. *Med Sci Sports Exerc 27:* S196, 1995
8. Clanton TO, Solcher BW: Chronic leg pain in the athlete. *Clin Sports Med 13:* 743–759, 1994
9. Clark CR: The prospective, randomized, double-blind clinical trial in orthopaedic surgery [Editorial]. *J Bone Joint Surg 79A:* 1119–1120, 1997
10. Coleman BD, Khan KM, Kiss ZS, et al: Open and arthroscopic patellar tenotomy for chronic patellar tendinopathy: A retrospective outcome study. *Am J Sports Med 28:* 183–190, 2000
11. Detmer DE, Sharpe K, Sufit RL, et al: Chronic compartment syndrome: Diagnosis, management, and outcomes. *Am J Sports Med 13:* 162–170, 1985
12. Edwards P, Myerson MS: Exertional compartment syndrome of the leg. Steps for expedient return to activity. *Physician Sportsmed 24(4):* 31–46, 1996
13. Fehlandt A Jr, Micheli L: Acute exertional anterior compartment syndrome in an adolescent female. *Med Sci Sports Exerc 27:* 3–7, 1995
14. Fronek J, Mubarak SJ, Hargens AR, et al: Management of chronic exertional anterior compartment syndrome of the lower extremity. *Clin Orthop 220:* 217–227, 1987
15. Humphries D: Exertional compartment syndromes. *Medscape Orthop Sports Med 3:* 1–6, 1999
16. Ioannidis JPA: Effect of the statistical significance of results on the time to completion and publication of randomized efficacy trials. *JAMA 279:* 281–286, 1998

17. Martens MA, Moeyersoons JP: Acute and recurrent effort-related compartment syndrome in sports. *Sports Med 9:* 62–68, 1990
18. McGrory BJ, Morrey BF, Rand JA, et al: Correlation of patient questionnaire responses and physician history in grading clinical outcome following hip and knee arthroplasty: A prospective study of 201 joint arthroplasties. *J Arthroplasty 11:* 45–57, 1996
19. Micheli LJ, Solomon R, Solomon J, et al: Surgical treatment for chronic lower-leg compartment syndrome in young female athletes. *Am J Sports Med 27:* 197–201, 1999
20. Padhiar N, King JB: An overview of chronic compartment syndrome: Commonest exercise induced leg pain in young athletes. *J Br Podiatr Med 50:* 50–53, 1995
21. Pedowitz RA, Hargens AR, Mubarak SJ, et al: Modified criteria for the objective diagnosis of chronic compartment syndrome of the leg. *Am J Sports Med 18:* 35–40, 1990
22. Puranen J: The medial tibial syndrome: Exercise ischaemia in the medial fascial compartment of the leg. *J Bone Joint Surg 56B:* 712–715, 1974
23. Qvarfordt P, Christenson JT, Eklof B, et al: Intramuscular pressure, muscle blood flow, and skeletal muscle metabolism in chronic anterior tibial compartment syndrome. *Clin Orthop 179:* 284–290, 1983
24. Reneman RS: The anterior and the lateral compartmental syndrome of the leg due to intensive use of muscles. *Clin Orthop 113:* 69–80, 1975
25. Rorabeck CH, Bourne RB, Fowler PJ: The surgical treatment of exertional compartment syndrome in athletes. *J Bone Joint Surg 65A:* 1245–1251, 1983
26. Rorabeck CH, Fowler PJ, Nott L: The results of fasciotomy in the management of chronic exertional compartment syndrome. *Am J Sports Med 16:* 224–227, 1988
27. Schepsis AA, Martini D, Corbett M: Surgical management of exertional compartment syndrome of the lower leg: Long-term followup . *Am J Sports Med 21:* 811–817, 1993
28. Stern JM, Simes RJ: Publication bias: Evidence of delayed publication in a cohort study of clinical research projects. *BMJ 315:* 640–645, 1997
29. Styf J: Chronic exercise-induced pain in the anterior aspect of the lower leg: An overview of diagnosis. *Sports Med 7:* 331–339, 1989
30. Sudmann E: The painful chronic anterior lower leg syndrome: A prospective clinical and experimental study. *Acta Orthop Scand 50:* 573–581, 1979
31. Turnipseed W, Detmer DE, Girdley F: Chronic compartment syndrome: An unusual cause for claudication. *Ann Surg 210:* 557–563, 1989
32. Wallenstein R: Results of fasciotomy in patients with medial tibial syndrome or chronic anterior-compartment syndrome. *J Bone Joint Surg 65A:* 1252–1255, 1983
33. Wiley JP, Clement DB, Doyle DL, et al: A primary care perspective of chronic compartment syndrome of the leg. *Physician Sportsmed 15(3):* 110–120, 1987