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# Relationship between models of care and key rehabilitation milestones following unilateral transtibial amputation: a national cross-sectional study

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## Abstract

**Objectives** To identify different models of care (MOC) post transtibial amputation (TTA) and relate these to achievement of rehabilitation milestones.
**Design** Retrospective analysis of rehabilitation milestone data and a survey of MOC in 10 vascular centres.
**Setting** NHS Scotland vascular centres.
**Participants** All unilateral TTA between January 2011 and December 2014 ($n = 643$).
**Main outcome measures** Time (in days) to achieve the following rehabilitation milestones: compression therapy, early walking aid, casting for a prosthetic limb, prosthetic delivery, inpatient discharge and final discharge from rehabilitation. MOC were scored according to seven key aspects of service provision.
**Results** The mean age of the cohort was 67 [standard deviation (SD) 13] years, 76% were male and 63% had peripheral arterial disease and diabetes. The median number of days to achieve rehabilitation milestones varied between centres {compression therapy six [interquartile range (IQR) 0–12], early walking aid 14 (IQR 10–27), prosthetic casting 39 (IQR 27–71), prosthetic delivery 53 (IQR 36–87), inpatient discharge 53 (IQR 29–85) and final discharge from rehabilitation 141 (IQR 92–209)}. Only two centres included all seven key aspects of service provision within their MOC. Vascular centres that achieved the optimal MOC achieved the rehabilitation milestones more quickly than other vascular centres.
**Conclusions** A positive association was found between optimal MOC and early achievement of rehabilitation milestones post TTA. Key aspects of service provision associated with a quicker time to achieve rehabilitation milestones included: use of a postoperative rigid dressing, specialist physiotherapy input in the early postoperative period, daily inpatient gym sessions and inpatient prosthetic provision. To the authors' knowledge, this is the first study to document MOC following TTA and to relate these to the achievement of rehabilitation milestones.


*Keywords:* Transtibial; Amputation; Models of care; Rehabilitation milestones; Prosthetics; Service design

## Introduction

Approximately 800 lower limb amputations are performed in Scotland each year. Of these, 85% are as a result of peripheral arterial disease (PAD) in the presence or absence of diabetes [1]. PAD and diabetes affect 2.7 million and 4.5 million people in the UK, respectively [2–4]. The affected population is predominantly elderly, has significant co-morbid disease, is at increased risk of contralateral limb amputation, and subsequently has a higher mortality rate [5,6]. Mortality rates after major lower limb amputation for PAD with or without diabetes are as high as 44%–48% at 1 year and 70%–77% at 5 years [7,8]. Therefore, it is critical that postoperative rehabilitation is optimal and not prolonged in order to maximise quality of life.

The primary focus of rehabilitation post amputation is the recovery of functional independence and a return to pre-amputation activity, which is more achievable if the

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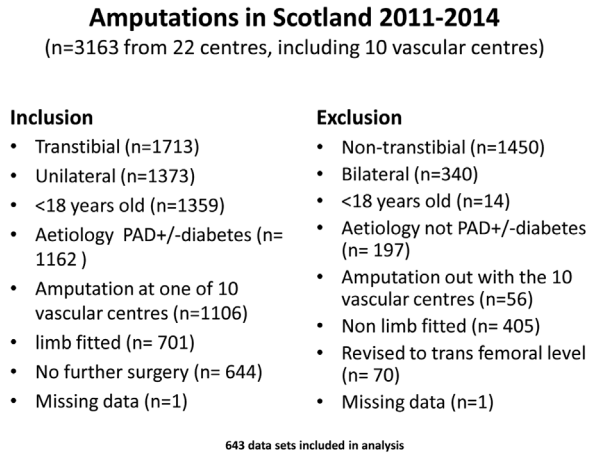



Fig. 1. Inclusion and exclusion criteria for Phase 1. PAD, peripheral arterial disease.

patient is fitted with a prosthetic limb. This is more realistic following a transtibial amputation (TTA) compared with a more proximal transfemoral amputation (TFA), as the loss of the knee joint greatly increases the physical and cognitive effort required. Data from the Scottish Physiotherapy Amputee Research Group (SPARG) show that approximately 70% of patients with TTA are fitted with a prosthetic limb, compared with 30% of patients with TFA (https://bacpar.csp.org.uk/publications/sparg-report-2015).

Prosthetic rehabilitation begins immediately after surgery, and includes compression therapy and re-education of gait using an early walking aid (EWA) [9]. In an ideal setting, compression therapy would start with application of a postoperative rigid dressing in theatre. The next line of compression is a shrinker sock, applied routinely from day 5 onwards [10]. Initial physiotherapeutic rehabilitation seeks to reduce the incidence of postoperative complications whilst promoting early mobility with an EWA and provision of a prosthetic limb [11,12]. The pneumatic post amputation mobility (PPAM) aid is the most commonly used EWA following unilateral TTA [13]. Early gait training is associated with satisfaction and daily usage of a prosthetic limb [14], and use of a prosthesis is associated with a reduced mortality rate [15] and increased independence and quality of life [11,12,14–16].

Physiotherapeutic intervention following amputation is determined by the model of care (MOC) in each vascular centre. There is a paucity of published literature defining the 'gold standard' MOC for patients undergoing TTA; however, variations in MOC have been identified across the UK [17]. SPARG identified large variations in MOC for patients undergoing rehabilitation after amputation in Scotland [1]. Intensive inpatient rehabilitation has been shown to be associated with improved outcomes in the USA [18,19], and in the UK, Turney et al. found that 'vigorous inpatient rehabilitation' was associated with 'mobility success' at the end of rehabilitation [20]. Despite this evidence, there is no current consensus regarding optimal MOC following amputation, and current guidelines do not make recommendations regarding the timing and type of rehabilitation [9]. The Scottish Rehabilitation Engineering Technology Group benchmarked amputation rehabilitation services across Scotland, and used this information to identify the seven key aspects of service provision [21]. The aim of this study was to identify the different MOC post TTA in Scotland, and explore how aspects of these MOC relate to the achievement of rehabilitation milestones. As patients with a TTA are more likely to be fitted with a prosthetic limb and therefore achieve rehabilitation milestones, this study focused solely on this level of amputation.

## Methods

This study was conducted in two phases. Phase 1 was a retrospective analysis of quantitative data collected from the SPARG database. SPARG carries out a national audit of routinely collected anonymised data on every person in Scotland who undergoes a major lower limb amputation. Data include information relating to aetiology, co-morbidities, timing of rehabilitation, key outcome measures and final outcome regarding limb fitting and mobility; the centre where the amputation was performed is also noted. To reduce variables within the cohort and with the aim of providing the most robust conclusions from the data, all participants (aged $\geq$18 years old) who underwent a unilateral TTA between 1 January 2011 and 31 December 2014 due to PAD and diabetes were included. Only the vascular centres with more than 20 unilateral TTA that were fitted with a prosthetic limb were included (Fig. 1). Due to increased variability within the sample, and given the aim of this study to provide robust conclusions from the data, all participants with aetiologies other than PAD and diabetes were excluded.

Data pertaining to the timing (in days) of achievement of the following six rehabilitation milestones were examined: compression therapy, early walking aid, casting for a prosthetic limb, prosthetic delivery, inpatient discharge and final discharge from rehabilitation. The cohort was categorised by the vascular centre where they underwent their TTA.

Phase 2 was a survey of MOC in the 10 vascular centres in Scotland. Each MOC was scored according to the key aspects of service provision, defined by the benchmarking report [21]. These seven aspects were: immediate postoperative rigid dressing, specialist physiotherapeutic assessment in first 14 days post TTA, daily inpatient gym session, inpatient gym session >1 hour, prosthetic centre on site as inpatient, prosthetic provision (i.e. cast, fit and delivery) as inpatient, and specialist physiotherapy outpatient service. Centres were given one point for each aspect of service provision that was included in their MOC; as such, the maximum score for each centre was seven points.

The final part of the study was to explore the relationship between achievement of the rehabilitation milestones and MOC scores. Descriptive analysis was performed using SPSS Version 22 [22]. A Shapiro–Wilk normality test found

that participant demographics were normally distributed; however, milestone data were not normally distributed, so parametric and non-parametric statistics were used as appropriate. The data were grouped according to vascular centre, and Kruskal–Wallis tests were performed to explore any differences in time to achieve the rehabilitation milestones between the vascular centres. Mann–Whitney *U*-tests were conducted to ascertain how centres compared, and if differences in time taken to reach milestones were significant. Statistical significance was set at $P<0.05$ and confidence intervals of 95% or more were assumed. Effect sizes were calculated and reported as follows: small (<0.1), medium (<0.3) and large (<0.5) [23].

## Results

The SPARG database indicated that 643 patients underwent a unilateral TTA between 2011 and 2014 and were fitted with a prosthetic limb. The mean age of this cohort was 67 (standard deviation 13) years, although this varied from 62 years in Centre 9 to 70 years in Centre 2 ($P=0.046$). There was a significant difference in age between aetiologies, as patients with PAD alone were approximately 4.7 years older than patients with both PAD and diabetes ($P<0.001$). The majority of the cohort was male (76%), and this ratio was similar across all centres ($P=0.451$). There was a significant difference in aetiology according to gender, with more males having both PAD and diabetes compared with females ($P=0.002$). Although the entire cohort had their TTA due to PAD, more than half also had a diagnosis of diabetes (63%), with fewer in Centre 4 (52%) and more in Centre 3 (79%) ($P=0.233$) (Table 1).

There was a significant difference between the centres for all six milestones (Table 2). Centres 3, 6, 7 and 10 had the shortest times to commence compression therapy, and Centre 8 had the shortest time to commence EWA use (Fig. 2). There was a significant difference in time to compression therapy between Centre 1 (median 14 days, $n=56$) and Centre 6 (median 0 days, $n=37$; $P<0.001$); the effect size was large, with Centre 1 taking longer to commence compression. There was a similar outcome when time to commence EWA was compared between Centre 2 (median 35 days, $n=50$) and Centre 6 (median 12 days, $n=33$; $P<0.001$); the effect size was large, with Centre 2 taking longer to commence EWA.

Centres 6, 7 and 8 had the shortest times to cast for a prosthetic limb (median 34 days, $n=37$; median 27 days, $n=94$; median 32 days, $n=165$, respectively) compared with Centre 2 (median 63 days, $n=53$). A significant difference was found between Centre 2 and Centre 6 ($P<0.001$), and the effect size was medium. Centre 6 and Centre 7 (median 35 and 34.5 days, respectively) had the fastest times to delivery of the prosthesis, and Centre 2 had the longest (median 87 days, $n=53$). When days to prosthetic delivery were compared between Centre 2 and Centre 6, this difference was significant ($P<0.001$) (Fig. 3).

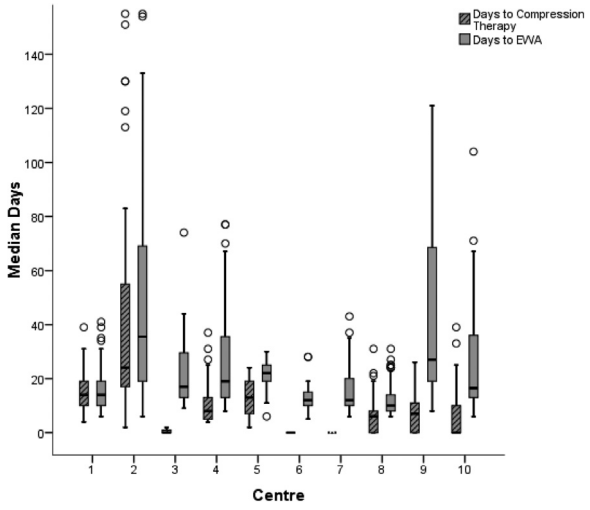



Fig. 2. Box plot of days to compression and use of early walking aids (EWA) across the vascular centres.

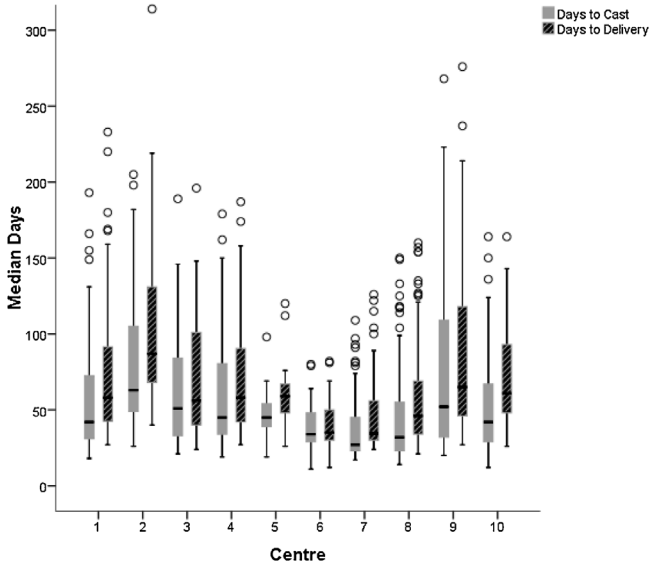



Fig. 3. Box plot of days to cast and delivery of prostheses across the vascular centres.

Centre 10 had the shortest inpatient stay after TTA (median 21 days), and this was approximately one-quarter of the length of inpatient stay observed in Centre 3 (median 83 days) and Centre 4 (median 85 days). Centre 6 had the shortest time to final discharge from rehabilitation (median 82 days), and this was significantly faster than the time to final discharge for the other nine centres (Fig. 4): Centre 1 (median 113 days, $n=59$); Centre 2 (median 213 days, $n=52$); Centre 3 (median 108 days, $n=33$); Centre 4 (median 126 days, $n=66$); Centre 5 (median 127 days, $n=21$); Centre 7 (median 101 days, $n=93$); Centre 8 (median 167 days, $n=136$); Centre 9 (median 137 days, $n=36$) and Centre 10 (median 169 days, $n=71$).

Table 1
Participant demographics across all vascular centres.

| | Vascular centres | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All ($n=643$) | 1 ($n=56$) | 2 ($n=53$) | 3 ($n=32$) | 4 ($n=66$) | 5 ($n=25$) | 6 ($n=37$) | 7 ($n=93$) | 8 ($n=162$) | 9 ($n=36$) | 10 ($n=72$) | *P*-value |
| Age in years, mean (SD) | 67 (13) | 66 (13) | 70 (12) | 66 (12) | 66 (14) | 68 (12) | 68 (12) | 70 (13) | 66 (12) | 62 (14) | 65 (11) | 0.046 |
| Males, *n* (%) | 488 (76) | 46 (78) | 36 (68) | 22 (67) | 57 (85) | 18 (72) | 28 (76) | 75 (80) | 121 (73) | 27 (73) | 58 (80) | 0.451 |
| Female, *n* (%) | 155 (24) | 13 (22) | 17 (32) | 11 (33) | 10 (15) | 7 (28) | 9 (24) | 19 (20) | 44 (27) | 10 (27) | 15 (21) | |
| PAD, *n* (%) | 239 (37) | 19 (32) | 19 (36) | 7 (21) | 32 (48) | 7 (28) | 14 (38) | 40 (43) | 61 (37) | 10 (27) | 30 (41) | 0.233 |
| PAD + diabetes, *n* (%) | 404 (63) | 40 (68) | 34 (64) | 26 (79) | 35 (52) | 18 (72) | 23 (62) | 54 (57) | 104 (63) | 27 (73) | 43 (59) | |

PAD, peripheral arterial disease; SD, standard deviation.

Table 2
Time taken (in days) to achieve rehabilitation milestones in all vascular centres.

| | Vascular centres | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to | All | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | *P*-value |
| Compression therapy | 6 (0 to 12) | 14 (10 to 20) | 25 (17 to 64) | 0 (0 to 1) | 8 (5 to 13) | 13 (7 to 19) | 0 (0 to 0) | 0 (0 to 0) | 6 (0 to 9) | 7 (1 to 11) | 0 (0 to 9) | <0.001 |
| EWA | 14 (10 to 27) | 14 (10 to 19) | 35 (19 to 69) | 17 (13 to 29) | 19 (13 to 38) | 22 (19 to 25) | 12 (10 to 15) | 12 (10 to 20) | 10 (8 to 14) | 27 (19 to 75) | 17 (13 to 36) | <0.001 |
| Casting | 39 (27 to 71) | 42 (31 to 74) | 63 (49 to 105) | 51 33 to 84) | 45 (34 to 81) | 45 (39 to 54) | 34 (29 to 48) | 27 23 to 45) | 32 (23 to 55) | 52 (32 to 109) | 42 (29 to 67) | <0.001 |
| Prosthetic delivery | 53 (36 to 87) | 58 (42 to 94) | 87 (68 to 131) | 56 (40 to 101) | 58 (42 to 91) | 59 (48 to 67) | 35 (30 to 50) | 34.5 (30 to 56) | 46 (34 to 69) | 65 (46 to 118) | 61 (48 to 93) | <0.001 |
| Inpatient discharge | 53 (29 to 85) | 77 (55 to 92) | 41 (21 to 81) | 83 (64 to 138) | 85 (65 to 126) | 66 (44 to 78) | 52 (43 to 84) | 62 (4 to 97) | 35 (23 to 57) | 35 (16 to 91) | 21 (14 to 41) | <0.001 |
| Outpatient discharge | 141 (92 to 209) | 113 (80 to 191) | 213 (165 to 309) | 108 (80 to 179) | 126 (86 to 174) | 127 (113 to 253) | 82 (62 to 114) | 101 (72 to 150) | 167 (119 to 224) | 137 (91 to 224) | 169 (123 to 255) | <0.001 |

EQA, early walking aid.
Values are median (interquartile range).
*P*-values represent findings from Kruskal–Wallis tests.

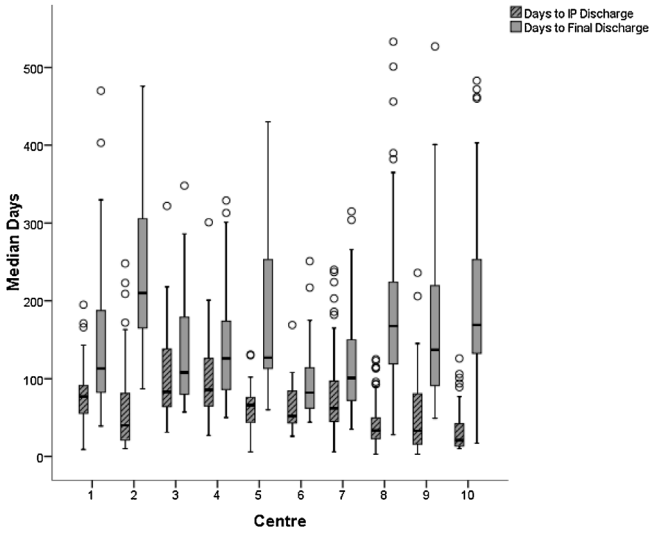
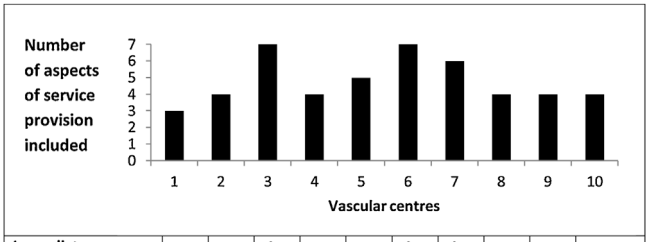



Fig. 4. Box plot of days to inpatient (IP) and final discharge from rehabilitation across the vascular centres.




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Immediate postoperative rigid dressing | | | √ | | | √ | √ | | | |
| Specialist physiotherapist in first 14 days | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Daily inpatient gym session (Mon to Fri) | | √ | √ | | √ | √ | √ | √ | √ | √ |
| Inpatient gym session ≥1 hour | | | √ | | | √ | √ | √ | √ | √ |
| Prosthetic centre on site when inpatient | | √ | √ | √ | | √ | √ | | | |
| Prosthetic provision as an inpatient | √ | | √ | √ | √ | √ | √ | | | |
| Specialist physiotherapy outpatient service | √ | √ | √ | √ | √ | √ | | √ | √ | √ |

Fig. 5. Aspects of service provision by vascular centre.

From analysis of the MOC data, only Centres 3 and 6 included all seven key aspects of service provision, while Centre 1 included less than half of the key aspects (Fig. 5).

## Discussion

To the authors' knowledge, this is the first study to identify the different MOC following unilateral TTA in Scotland. It is also the first study to compare vascular centres in terms of time taken to achieve rehabilitation milestones. This study found an association between MOC and the time taken to achieve these rehabilitation milestones. MOC in this study were based upon the benchmarking of seven key aspects of service provision.

The first aspect is the use of compression therapy to help reduce oedema and accelerate rehabilitation. Current evidence suggests that this should be started in theatre at the time of TTA with a postoperative rigid dressing [10,24]. Centres 3, 6 and 7 stated that they used rigid dressings routinely after surgery and the data supported this. Centre 10 also used rigid dressings but their application was not routine in all surgeries {median 0 [interquartile range (IQR) 0–9] days}. Centre 6 was one of the centres with the fastest times to commence EWA use [median 12 (IQR 10–15) days], along with Centre 7 [median 12 (IQR 10–20) days] and Centre 8 [median 10 (IQR 8–14) days].

The EWA of choice was the PPAM aid, which applies compression to the residuum; in combination with the effect of mobilisation on the cardiovascular system, this increases circulation, reduces oedema and promotes wound healing, which are essential to allow early prosthetic fitting [24,25]. All 10 centres used the PPAM aid routinely; however, the use of PPAM aids commenced from median 10 days to median 35 days after TTA (Table 2). Gym sessions have a direct impact on timing, duration and frequency of the use of PPAM aids, as they are physiotherapy devices. Centres 7 and 8 had the longest gym sessions and provided these on 5 days per week. Interestingly, although Centre 8 took longer to commence compression therapy [median 6 (IQR 0– 9) days] and did not use rigid dressings routinely, it had the fastest time to start EWA use [median 10 (IQR 8–14) days]. The specialist physiotherapists at Centres 7 and 8 were the only teams whose remit was solely vascular, allowing them to deliver longer gym sessions within the first 14 days, thus promoting early mobility.

The current literature supports comprehensive and intensive inpatient rehabilitation post amputation [19,26]. In these studies, optimal outcomes were associated with provision of a prosthetic limb and completing rehabilitation as an inpatient. In this study, the median length of inpatient stay varied from 21 to 85 days (Centres 10 and 4, respectively). Interestingly, Centre 10, which had the shortest inpatient stay, also had one of the longest times to final discharge from rehabilitation (median 169 days). Centre 10 also started EWA use [median 17 (IQR 13–36)] in a similar time frame as the patient was discharged home from hospital [median 21 (IQR 14–41) days].

A delay in provision of a prosthetic limb (>60 days post TTA), even after controlling for demographic, socio-

economic and amputation-related characteristics, has been shown to be associated with dissatisfaction with the device and, therefore, a reduction in its use [27]. Although Centres 6, 7 and 8 had the quickest times for cast and delivery of the prosthetic limb, Centre 8 did not have a prosthetic service on site; as such, it took the longest of these three centres for cast and delivery. Conversely, Centre 2 was the slowest to achieve all rehabilitation milestones and had a prosthetic service on site. The delayed time for cast and delivery in Centre 2 may be attributed to the delay in starting compression therapy and EWA use as there is a known link between mobility with an EWA and reduction in stump volume in preparation for casting of the prosthetic limb [10]. Centre 2 also had a physiotherapy team that was not designated solely to vascular, and despite provision of daily gym sessions, these did not exceed 1 hour in length. The demographics of the cohort at Centre 2 were not dissimilar to others in terms of gender and aetiology; however, they were the oldest cohort of all the centres (mean age 70 years), which may be a factor in the increased length of time taken to achieve milestones.

The time taken to reach rehabilitation milestones is important in the amputee population as many will have a shortened life expectancy due to their high mortality rate and additional co-morbidities [7,8]. Increased mortality is also associated with delayed decision making prior to amputation, and not being fitted with a prosthetic limb following amputation [15,16,28]. Achieving the key rehabilitation milestones in the shortest time may reduce mortality and improve usage of the prosthesis, which may impact positively on quality of life in this population. Centre 6, which provided all seven key aspects, reached key rehabilitation milestones in fewer days for five of the six milestones. This suggests that the MOC is associated with time taken to achieve rehabilitation milestones following a unilateral TTA. However, Centre 3 also had an optimum MOC score according to the seven aspects, but did not achieve the rehabilitation milestones more quickly. The reason for this may be that their patients had a higher incidence of diabetes than any other centre (79%), which has a known impact on healing time and complications post operatively [29].

A strength of the current study is its large retrospective cohort, which was a consecutive sample of all patients with a TTA who were fitted with a prosthetic limb in Scotland, therefore increasing the external validity of the study and the ability to generalise the results to other populations. This data set is also the most up-to-date, intact data set for the vascular centres being discussed. One of the observations of this study was the variance in numbers across the vascular centres; however, the consecutive sampling of the patients aids with the validity of the data. Centres 7 and 8 had the highest number of patients ($n = 93$ and 162, respectively), whereas Centre 5 had the lowest number ($n = 25$). With varying numbers in the 10 centres, there may be a large variation in experience of the physiotherapy staff and understanding of how to best achieve rehabilitation milestones as quickly as possible.

## Conclusions

The aim of this study was to identify the different MOC following unilateral TTA in Scotland, and explore how they relate to the achievement of rehabilitation milestones. MOC varied across the vascular centres in Scotland, and there was significant disparity in the timing of rehabilitation milestone achievements following unilateral TTA. The ability to achieve a short time for cast and delivery of a prosthetic limb appears to be influenced not only by the presence of a prosthetic service on site, but also by commencing compression therapy and EWA use in a timely manner. The latter is only possible with a specialist physiotherapist and frequent gym sessions. Given the high mortality rate of the dysvascular lower limb population, it is imperative that these services are available to provide the most effective rehabilitation in the shortest time.

**Key messages**

- This paper provides the first comprehensive identification and exploration of models of care post transtibial amputation in Scotland.
- Key aspects of service provision associated with a quicker time to achieve rehabilitation milestones included: use of a postoperative rigid dressing, specialist physiotherapy input in the early postoperative period, daily inpatient gym sessions and inpatient prosthetic provision.

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