



■ CHILDREN'S ORTHOPAEDICS

A 'Hub and Spoke' Shared Care initiative for CTEV Ponseti service

DELIVERING HIGH STANDARDS ACCORDING TO THE BRITISH CONSENSUS STATEMENT COMBINED WITH GEOGRAPHICAL ACCESSIBILITY

**S. A. Hussain,
A. Russell,
S. E. Cavanagh,
A. Bridgens,
Y. Gelfer**

From St George's
Hospital, London, UK

Aims

The Ponseti method is the gold standard treatment for congenital talipes equinovarus (CTEV), with the British Consensus Statement providing a benchmark for standard of care. Meeting these standards and providing expert care while maintaining geographical accessibility can pose a service delivery challenge. A novel 'Hub and Spoke' Shared Care model was initiated to deliver Ponseti treatment for CTEV, while addressing standard of care and resource allocation. The aim of this study was to assess feasibility and outcomes of the corrective phase of Ponseti service delivery using this model.

Methods

Patients with idiopathic CTEV were seen in their local hospitals ('Spokes') for initial diagnosis and casting, followed by referral to the tertiary hospital ('Hub') for tenotomy. Non-idiopathic CTEV was managed solely by the Hub. Primary and secondary outcomes were achieving primary correction, and complication rates resulting in early transfer to the Hub, respectively. Consecutive data were prospectively collected and compared between patients allocated to Hub or Spokes. Mann-Whitney U test, Wilcoxon signed-rank test, or chi-squared tests were used for analysis (alpha-priori = 0.05, two-tailed significance).

Results

Between 1 March 2020 and 31 March 2023, 92 patients (139 feet) were treated at the service (Hub 50%, n = 46; Spokes 50%, n = 46), of whom nine were non-idiopathic. All patients (n = 92), regardless of allocation, ultimately achieved primary correction, with idiopathic patients at the Hub requiring fewer casts than the Spokes (mean 4.0 (SD 1.4) vs 6.9 (SD 4.4); $p < 0.001$). Overall, 60.9% of Spokes' patients (n = 28/46) required transfer to the Hub due to complications (cast slips Hub n = 2; Spokes n = 17; $p < 0.001$). These patients ultimately achieved full correction at the Hub.

Conclusion

The Shared Care model was found to be feasible in terms of providing primary correction to all patients, with results comparable to other published services. Complication rates were higher at the Spokes, although these were correctable. Future research is needed to assess long-term outcomes, parents' satisfaction, and cost-effectiveness.

Cite this article: *Bone Jt Open* 2023;4-11:865–872.

Keywords: Ponseti, CTEV, Hub and Spoke, Service delivery, Primary correction, Paediatrics, Clubfoot, Model, Complication rates

Correspondence should be sent to
Sabba A. Hussain; email:
sabbahussain@doctors.org.uk

doi: 10.1302/2633-1462.411.BJO-
2023-0076.R1

Bone Jt Open 2023;4-11:865–872.

Introduction

The Ponseti method is the gold standard treatment for patients with congenital talipes equinovarus (CTEV),¹ which affects

approximately one to three per 1,000 births.² It involves serial casting,³ followed by Achilles tenotomy and a bracing regime. This service delivery requires specialized and

highly trained practitioners.⁴ Based on the British Society for Children's Orthopaedic Surgery (BSCOS) consensus statement for CTEV management,⁵ delivery within an established Ponseti clinic is the desirable standard of care in the UK.^{5,6} This clinic design carries a substantial case-load and thus requires expertise to both identify and treat various pathologies, and to provide accurate decision-making and continuity of care.

Various models of Ponseti service delivery have been reported in the literature, including either independent provision or a combination of physiotherapists, surgeons, or healthcare practitioners (HCPs) (such as in low- and middle-income countries (LMICs)).^{4,7-13} Previous studies have shown that a physiotherapy-led service is as efficient as a surgeon-led service with comparable primary outcomes.^{4,14,15} The best geographical model is yet to be determined.

The most common challenges faced in Ponseti service delivery is providing a service that is both at a high standard¹⁶ and geographically accessible.¹⁷ This is applicable for both the UK and other countries, specifically LMICs, where it is often difficult for families to travel to specialized Ponseti clinics.¹⁷⁻¹⁹ Patients may be treated in large centres with a great deal of experience, or may be treated more locally to increase attendance and compliance (as this condition requires continuous long-term follow-up),⁵ albeit by a team that may have exposure to fewer cases per year.

The 'Hub and Spoke model' for service delivery has been trialled successfully in the NHS in the UK across different specialties,²⁰⁻²² combining the expertise of tertiary centres with the locality of regional hospitals. This model has been implemented at St George's Hospital, London, UK (tertiary centre) and associated district general hospitals (DGHs) for the delivery of elective paediatric orthopaedic care for over 15 years. The service delivers elective paediatric orthopaedic care to the entire region with the Hub, treating patients that require surgery, as well as paediatric intensive care unit (PICU) and complex multidisciplinary team (MDT) input; and the regional services providing clinic appointments with the support of local allied health and administrative teams. This model has addressed the lack of room capacity, parking, and managerial support in tertiary centres as well as the logistical challenges associated with travel for the patient and family. During the COVID-19 pandemic, the Ponseti service at St George's Hospital implemented a unique Hub and Spoke Shared Care model for the Ponseti service delivery for CTEV.⁷

The aim of this prospective study was to assess the short-term clinical outcomes of the corrective phase of Ponseti treatment managed under this model, and to consider the feasibility of its delivery for Ponseti service.

Methods

Hub and Spoke model. The St George's Ponseti Hub and Spoke Shared Care model consists of a central tertiary centre (St George's Hospital) with four paediatric orthopaedic consultant surgeons (AB, YG), one highly experienced advanced physiotherapy practitioner ('band 8') (AR), two Ponseti-trained physiotherapists ('band 7'), and one junior practitioner ('band 4'). There are four Spokes DGHs within the region (Figure 1a). Each regional service is composed of two to three Ponseti-trained physiotherapists, with a supervising paediatric orthopaedic consultant from the tertiary centre. This Ponseti service follows the BSCOS consensus statement,⁵ from clinic setup, prenatal counselling, manipulation, casting, tenotomy, bracing, follow-up, and documentation standards. Training and ongoing support is provided to the regional teams. This includes teaching days with practical workshops and lectures, educational visits from the lead practitioner, and attendance of Spokes practitioners at Hub appointments for the further development of skills.

Patients are allocated to start their treatment at either the Hub or one of the Spokes based on their address (Figure 1b). Patients with idiopathic CTEV are managed with prenatal counselling, baseline assessment, and primary casting in their local hospital (either the Hub or the Spokes). For patients allocated to the Spokes, the pre-tenotomy appointment, any remaining casts and all tenotomies are performed in the Hub Ponseti clinic. The tenotomy appointment is booked provisionally prior to treatment to avoid delays or unnecessary additional casts (Supplementary Figure a). Following tenotomy, the idiopathic patients are followed up at their Spoke hospital. Patients who are initially allocated to the Hub remain there throughout the course of their treatment. Primary boots and bar fitting can be done at either centre on a case-by-case basis. The service follows a comprehensive referral and treatment pathway for any complications or challenges during casting and for referral of all non-idiopathic CTEV, as per the BSCOS consensus statement (Figure 1b, Supplementary Figure a, Supplementary Table i).⁵ Patients with non-idiopathic CTEV, recurrent CTEV, and external referrals are managed solely at the Hub.

Inclusion and exclusion criteria. All consecutive infants with CTEV (idiopathic or non-idiopathic (atypical, complex, or with an underlying neuromuscular condition such as spina bifida)), age under six months at the start of correction, treated under this Shared Care Ponseti service from 1 March 2020 to 31 March 2023, were included. Infants born with foot deformities other than CTEV, aged older than six months at the start of treatment, with recurrent CTEV, or referred from elsewhere, were excluded.

Outcomes. The primary outcome measure was the rate of primary correction, which was defined as per the BSCOS statements (i.e. where the talar head is covered, with a

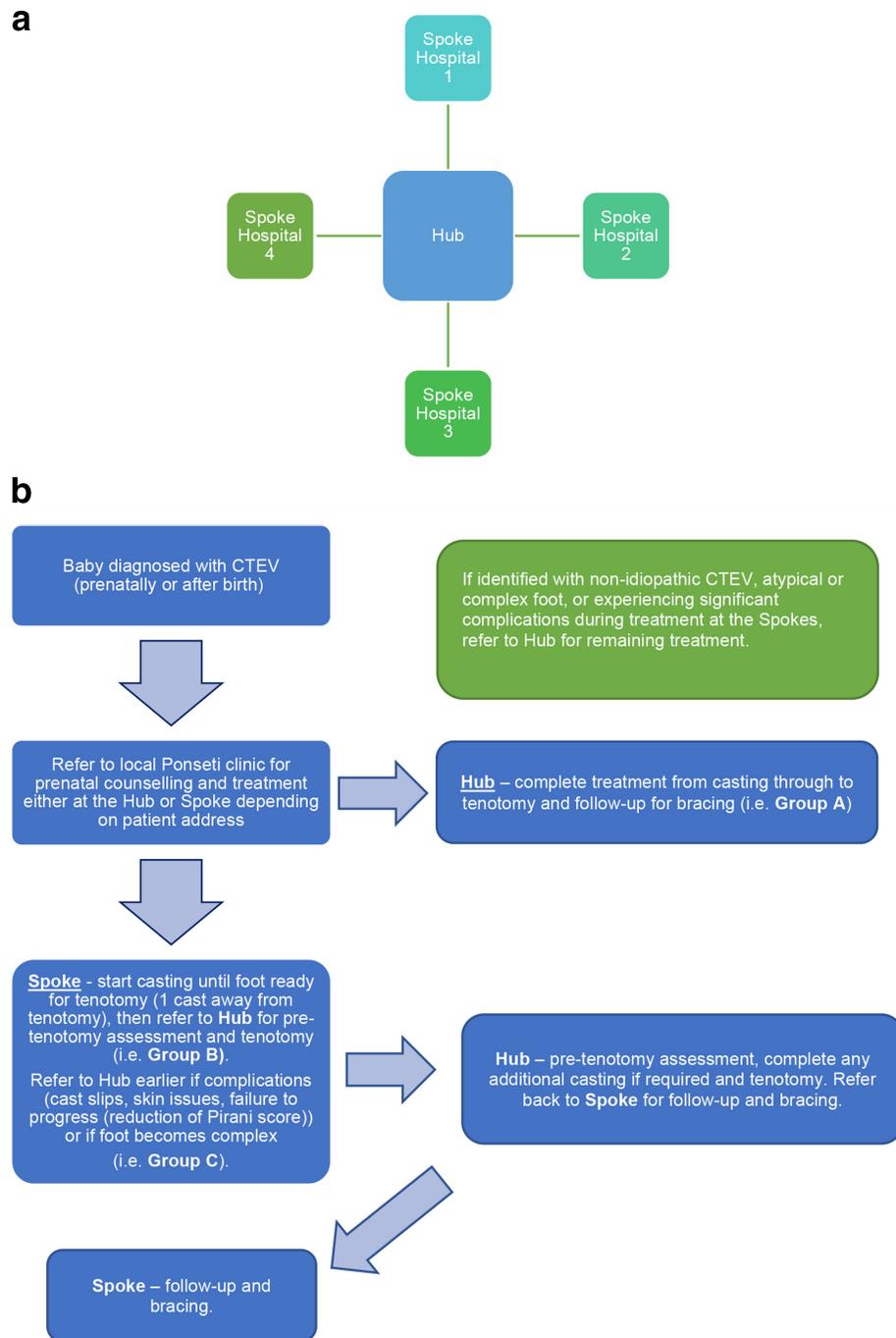


Fig. 1

a) Diagram of the Hub and Spoke Shared Care model. b) Overview of the patient pathway. CTEV, congenital talipes equinovarus.

neutral or valgus heel, and anterior process of the os calcis is rotated out under the talus, with at least 15° of ankle dorsiflexion).^{5,23} Secondary outcome measures included the number of casts required for correction, and the incidence of any complications related to casting (cast slips, pressure ulcers or skin issues that required a change to the casting schedule and a referral to the Hub centre).

Statistical analysis. This project was prospectively registered (Registration number AUDI003484). The

prospectively collected departmental database was visited. Data were collated using Microsoft Excel v16.70 (Microsoft, USA). Data including diagnosis, involved feet, sex, comorbidity, initial Pirani score, year treated, primary correction, number of casts, and complications related to Ponseti treatment for the Hub and the Spokes were analyzed.

For the purpose of comparison and reducing type I errors, all the Spoke centres were combined into one

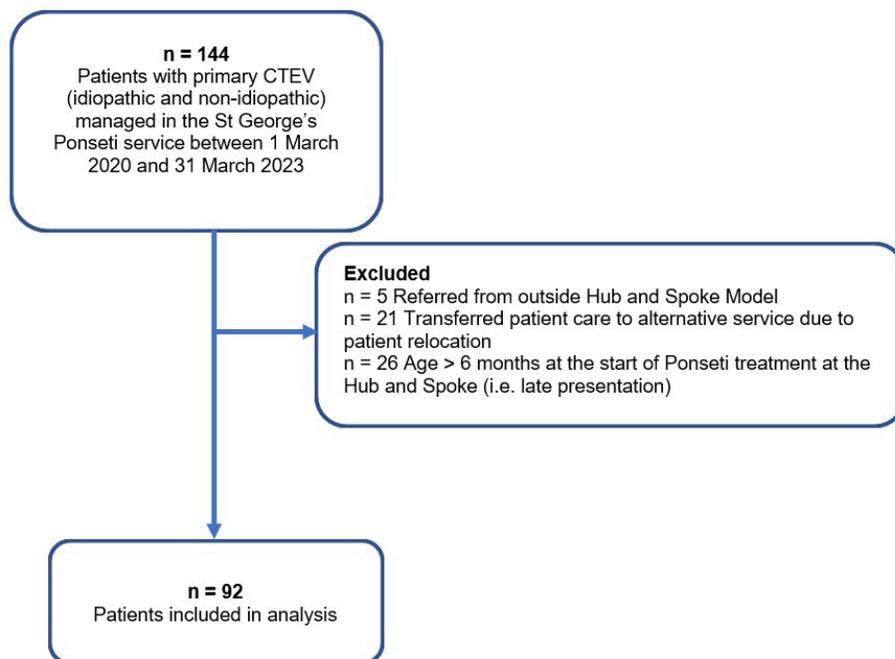


Fig. 2

Flowchart of patients included and excluded from analysis. CTEV, congenital talipes equinovarus.

group (labelled 'Spokes'). Comparisons were made between treatment outcomes of idiopathic CTEV patients who were allocated for treatment either at the Hub or Spokes based on their address. Group A was composed of idiopathic CTEV patients who received treatment from start to finish at the Hub. Idiopathic CTEV patients allocated to the Spokes were divided into two groups: Group B received treatment from start to finish at the Spokes (going to the Hub only for tenotomy or single pre-tenotomy cast); and Group C was composed of patients who were transferred to the Hub after receiving initial casting from the Spokes (due to lack of progression, capacity, or complications (as per the referral pathway)) (Figure 1). Outcome data for non-idiopathic CTEV managed at the Hub were analyzed separately.

Statistical analysis was carried out using GraphPad Prism v9.5.1 (GraphPad Software, USA). Results from the Shapiro-Wilk tests demonstrated that the data were not normally distributed, therefore non-parametric tests were used. Outcome data were compared between patients initially allocated to the Hub (A) or initially allocated to the Spokes (i.e. B and C), using the Mann-Whitney U test or chi-squared test as appropriate. Outcome data were compared within Group C to assess differences in management between the Spokes and Hub using the Wilcoxon signed-rank test or chi-squared test as appropriate. Data were compared between patients initially allocated to the Spokes (B vs C) to assess differences in baseline characteristics using the Mann-Whitney U test or chi-squared test as appropriate. Statistical significance

was set to an alpha-priori of 0.05 and was two-tailed. Data have been reported to one to three decimal points where appropriate.

Results

From 1 March 2020 to 31 March 2023, 92 patients (139 feet) treated at the Hub and Spoke Shared Care Ponseti service fitted the inclusion criteria, with 46 patients receiving care at the Hub (50%) and 46 at the Spokes (50%) (Figure 2, Table I). From the Spokes, 28 patients (n = 28/46, 60.9%) started their treatment locally and were transferred to the Hub due to failure to progress or complications (i.e. Group C) (Table II, Table III). All feet ultimately achieved primary correction (100%) (Table II).

Patient baseline presentation was largely similar between the Hub and Spokes, with the majority of patients being male (69/92, 75%), presenting with bilateral CTEV (47/92, 51.1%), idiopathic (83/92, 90.2%), and with a mean initial Pirani score of 4.4 (standard deviation (SD) 1.2). The Hub treated more patients with underlying comorbidities including congenital disorders compared to the Spokes, which included benign comorbidities (10/46, 21.7%; 5/46, 10.9%, respectively), reflecting the referral pathway (Table I).

Nine infants under the age of six months with non-idiopathic CTEV were managed at the Hub, out of which four were referred from the Spokes before initiation of treatment. Other children with non-idiopathic CTEV were excluded from analysis, as they had not initiated treatment under the Hub and Spoke model (Figure 2).

Table I. Baseline demographics of patients managed across the Hub and Spoke Shared Care model.

| Variable | Total | Treatment started at Hub | Treatment started at Spokes |
|---------------------------------------|------------|--------------------------|-----------------------------|
| Patients, n (%) | 92 (100.0) | 46 (50.0) | 46 (50.0) |
| Laterality, n (%) | | | |
| Right | 27 (29.3) | 12 (26.1) | 15 (32.6) |
| Left | 18 (19.6) | 11 (23.9) | 7 (15.2) |
| Bilateral | 47 (51.1) | 23 (50.0) | 24 (52.2) |
| Feet, n | 139 | 69 | 70 |
| Sex, n (%) | | | |
| Male | 69 (75.0) | 35 (76.1) | 34 (73.9) |
| Female | 23 (25.0) | 11 (23.9) | 12 (26.1) |
| Diagnosis, n (%) | | | |
| Idiopathic | 83 (90.2) | 37 (80.4) | 46 (100.0) |
| Non idiopathic | 9 (9.8) | 9 (19.6) | 0 (0.0) |
| Comorbidity, n (%) | 15 (16.3) | 10 (21.7) | 5 (10.9) |
| Mean initial Pirani score (SD) | 4.4 (1.2) | 4.2 (1.2) | 4.7 (1.2) |
| Year treatment started, n (%)* | | | |
| 2020 | 23 (25.0) | 13 (28.3) | 10 (21.7) |
| 2021 | 28 (30.4) | 16 (34.8) | 12 (26.1) |
| 2022 | 36 (39.1) | 15 (32.6) | 21 (45.7) |
| 2023 | 5 (5.4) | 2 (4.3) | 3 (6.5) |

*From 1 March 2020 until 31 March 2023.

SD, standard deviation.

Table II. Comparison of final treatment outcomes between idiopathic congenital talipes equinovarus (CTEV) patients initially allocated at the Hub versus Spokes.

| Outcome | Total across Shared Care Hub and Spoke Initiative | Idiopathic patients initially allocated to Spokes | | | p-value* |
|--|---|---|---|---|----------|
| | | Idiopathic patients initially allocated to Hub | Idiopathic patients initially allocated to Spokes | Final outcomes of patients transferred to Hub (including initial casting at Spokes) (C) † | |
| | | Complete casting at the Hub (A) | Complete casting at the Spokes (B) | Total for patients initially allocated to Spokes (B & C) | |
| Total, n | 83 | 37 | 18 (39.1%) | 46 | |
| Primary correction completed, n (%) | 83 (100.0) | 37 (100.0) | 18 (100.0) | 46 (100.0) | |
| Mean number of casts performed (SD; range) | 5.6 (3.7; 2 to 23) | 4.0 (1.4; 2 to 7) | 4.7 (0.8; 3 to 6) | 8.4 (5.1; 2 to 23) | < 0.001§ |
| Tenotomies performed, n (%)‡ | 82 (98.8) | 37 (100.0) | 18 (100.0) | 27 (96.4) | 0.204¶ |
| Complications related to casting | | | | | |
| Patients with cast slips, n (%) | 19 (22.9) | 2 (5.4) | 3 (16.7) | 14 (50.0) | < 0.001¶ |
| Total number of cast slips | 62 | 2 | 5 | 55 | |
| Mean number of cast slips per patient with a cast slip (SD; range) | 3.3 (4.0; 1 to 17) | 1 (0; 1 to 1) | 1.7 (0.6; 1 to 2) | 3.9 (4.5; 1 to 17) | < 0.001§ |
| Patients with skin issues requiring change of treatment, n (%) | 6 (7.2) | 1 (2.7) | 1 (5.6) | 4 (14.3) | 0.153¶ |
| Total number of skin issues | 9 | 1 | 1 | 7 | |

*P-values were calculated between Group A and Group B & C to compare whether initial allocation (to Hub or Spoke) affected outcome (reported to three decimal places).

†Patients who experienced numerous complications following initial treatment at the Spokes were transferred to the Hub (i.e. Group C)

‡All tenotomies were performed at the Hub for those patients who required tenotomy.

§Mann-Whitney U test.

¶Chi-squared test.

SD, standard deviation.

Incidence of patients treated at the Spokes increased with time, whereas numbers at the Hub remained static (Table I).

All patients eventually achieved primary correction regardless of where initial treatment was carried out (Table II). For patients whose treatment started at the

Table III. Breakdown comparison of treatment outcomes for Group C (n = 28) between treatment at Hub versus Spokes.

| Outcome | Initial treatment from Spokes | Remaining treatment from Hub | p-value* |
|---|-------------------------------|------------------------------|----------|
| Mean number of casts performed (SD; range) | 6.6 (3.6; 3 to 16) | 4.4 (1.6; 2 to 8) | 0.079† |
| Complications related to casting | | | |
| Patients with cast slips, n (%) | 13 (46.4) | 4 (14.3) | 0.009‡ |
| Mean number of cast slips of patients who had a cast slip (SD; range) | 3.9 (4.4; 1 to 16) | 1 (0; 1 to 1) | < 0.001† |
| Total number of cast slips | 51 | 4 | |
| Patients with skin issues requiring change of treatment, n (%) | 4 (14.3) | 0 (0) | |
| Total number of skin issues | 7 | 0 | |

*P-values calculated within Group C to compare differences in outcomes between Hub and Spoke (reported to three decimal points)

†Wilcoxon signed-rank test.

‡Chi-squared test.

SD, standard deviation.

Table IV. Comparison of baseline demographics of patients initially allocated to Spokes.

| Variable | Complete casting at the Spokes (B) | Transferred to Hub after initial casting at Spokes (C) | p-value* |
|-----------------------------------|------------------------------------|--|----------|
| Patients, n | 18 | 28 | |
| Laterality, n | | | 0.087‡ |
| Right | 9 | 6 | |
| Left | 1 | 6 | |
| Bilateral | 8 | 16 | |
| Sex, n | | | 0.113‡ |
| Male | 11 | 23 | |
| Female | 7 | 5 | |
| Comorbidity, n | 2 | 3 | 0.966‡ |
| Mean initial Pirani score (SD) | 4.6 (1.1) | 4.7 (1.3) | 0.618§ |
| Year treatment started, n† | | | 0.817‡ |
| 2020 | 4 | 6 | |
| 2021 | 6 | 6 | |
| 2022 | 7 | 14 | |
| 2023 | 1 | 2 | |

*P-values calculated between patients initially allocated to Spokes, to assess whether there was a significant difference in underlying characteristics that affected susceptibility to transfer to the Hub (reported to three decimal points).

†From 1 March 2020 until 31 March 2023.

‡Chi-squared test.

§Mann-Whitney U test.

SD, standard deviation.

Spokes, 39.1% (n = 18/46) achieved primary correction (Group B) at the local centre, and the remaining 60.9% (n = 28) had to be referred to the Hub (Group C) where 100% went on to ultimately achieve primary correction. Idiopathic patients treated at the Hub (A) required mean fewer casts than patients initially allocated to the Spokes (B & C) (A: 4.0 (SD 1.4); B & C: 6.9 (SD 4.4); p < 0.001, Mann-Whitney U test). All patients who required tenotomy received it at the Hub (n = 82/83, 98.8%) as per protocol (Table II).

Cast slips were more frequent at the Spokes (A: n = 2/37; B & C: n = 17/46; p < 0.001, chi-squared test). A total of 17 patients experienced cast slips with mean number

Table V. Final treatment outcomes of non-idiopathic congenital talipes equinovarus patients managed at the Hub.

| Outcome | Non-idiopathic patients managed at the Hub (across the Shared Care model) |
|--|---|
| Total, n | 9 |
| Primary correction completed, n (%) | 9 (100.0) |
| Mean number of casts performed (SD; range) | 4.1 (2.1; 2 to 9) |
| Tenotomies performed, n (%) | 8 (88.9) |
| Complications related to casting | |
| Patients with cast slips, n (%) | 1 (11.1) |
| Total number of cast slips | 1 |
| Patients with skin issues requiring change of treatment, n (%) | 1 (11.1) |
| Total number of skin issues | 1 |

SD, standard deviation.

of 3.5 (SD 4.1), compared to the Hub groups, where two patients experienced single cast slips (p < 0.001, Mann-Whitney U test). One patient managed at the Hub experienced skin complications, compared to five at the Spokes (p = 0.153, chi-squared test) (Table II).

For Group C, patients experienced fewer cast slips after transfer to the Hub (Spokes: n = 13/28; Hub: n = 4/28; p = 0.009, chi-squared test) (Table III). Anecdotally, patients transferred to the Hub for Group C were more complex than Group A; however, the number of casts required for Group C once transferred to the Hub was not different to patients who received the entirety of treatment at the Hub (Group A) (A: 4.0 (SD 1.4); C: Hub 4.4 (SD 1.6); p = 0.568, Mann-Whitney test).

Differences in underlying characteristics between Groups B and C were assessed and found to be insignificant across all available demographics (Table IV).

All non-idiopathic CTEV patients achieved primary correction (n = 9), with one experiencing a cast slip and another a minor skin complication (Table V).

Discussion

All patients managed at the St George's Ponseti service during the study period ultimately achieved primary

correction regardless of group. Out of the patients initially treated at the Spokes, 60.9% required transfer to the Hub as per the patient pathway, and ultimately required additional casts to achieve correction.

Rates of complications were higher at the Spokes, which resulted in these patients being transferred to the Hub. Cast slips can be reversible complications when identified and addressed in a timely manner. However, left unidentified they can potentially lead to the development of a 'complex' foot, which is more challenging to treat.²⁴ Early identification of slips in this model allowed early referral to the Hub, with primary correction ultimately achieved in all patients. The additional number of casts required at the Spokes (mean Hub 4.0 vs Spokes 6.9), although statistically significant, should not be clinically significant. The effect of transfer of care to the Hub, or resultant increase in number of casts on the family-perceived experience, was not assessed but as all patients ended up achieving primary correction the primary outcome had been satisfied.

The service potentially allows for sustainability in delivering Ponseti treatment with improving education and skill levels of physiotherapists and other HCPs at the Spokes through teaching programmes, one-on-one input, shadowing, and mentoring opportunities. It is safe to assume that with consistent and focused support, increasing training, and rigorous adherence to the pathway, the number of these short-term complications and delays would diminish. This would require regular performance auditing of the model.

Indeed, the service was highlighted as a case study by the NHS Paediatric Orthopaedics Getting It Right First Time (GIRFT) report.²⁵ The case study highlighted the service's benefits for carers and resource allocation as well as its sustainability. Benefits of the Hub and Spoke model allowed for geographical accessibility. This allows for reduced disruption in development for babies,²⁶ diminishes travel costs and time spent, which is a particular burden for families in less affluent areas and LMICs,²⁷ and is a notable cause of non-compliance¹⁷ and barrier to treatment.^{18,19} The model also provides a comparative advantage to the tertiary Hub in that it improves allocation of human and equipment resources to manage complex feet that may require MDT input, which is a substantial challenge faced in LMICs.¹⁶

The results demonstrated the Hub and Spoke model to be feasible in terms of providing primary correction to all patients, with results comparable to or better than other international published series from the UK and other countries.^{4,28-32} In addition, the service may be replicable in other areas such as with the Uganda project,¹³ where highly experienced human resources are particularly limited,^{4,7-13} therefore allowing for HCPs to start Ponseti treatment in local areas before referring for final input from centres with more specialist staff.

Other models of service delivery may have their merits as different settings may require a distinctive, tailored approach.^{4,7-13} It could be argued that centralizing the expertise in large tertiary centres results in better outcomes. This argument and the feasibility of its implementation remains to be determined. Individual locations should consider what is more appropriate for their local population, whether it is feasible for the expertise to be centralized and whether patients can be compliant with travelling to central locations.

There were a few limitations to this study. As the Hub and Spoke Shared Care model was initiated in 2020, data on the maintenance phase (including bracing) and any long-term outcomes in this population are yet to be collected. Patients who started treatment before introduction of the model were not included, and thus results are not reflective of other patients managed in the region. This study could not allow for a direct comparison of results of service delivery to an alternative model, as this model is perceived to be the most feasible for this particular area. It has been assumed that less travel and more accessibility is beneficial to families, but this study did not include family satisfaction and perception of this model.

In conclusion, to our knowledge this is the first report of instigating a 'Hub and Spoke' Shared Care model for service delivery of Ponseti treatment. The data from the first three years of its implementation show more complications during the casting period at the Spokes, ultimately with 100% primary correction rate. With continuous support, training, and experience, it is expected that the need for input from the Hub will reduce and cost-effective resource distribution can be achieved. Benefits of the model include improved logistics and allocation of resources, as well as maintaining local skill. Future research is needed to assess the long-term outcomes of treatment under this model, parents' satisfaction, and cost-effectiveness.



Take home message

- The St George's Hub and Spoke Shared Care model was effective and feasible in terms of delivering 100% primary correction to babies treated with Ponseti casting for congenital talipes equinovarus, albeit with increased complication rates at the Spokes.
- Benefits of the model include improved logistics for service delivery and families, and allocation of resources as well as maintaining local skill.
- Individual regions should consider the best delivery model for their local population.

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Supplementary material



Diagram of referral pathway of patients in the Hub and Spoke Shared Care Model; table showing complete congenital talipes equinovarus management schedule.

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Author information:

- S. A. Hussain, BSc (Hons), MBBS (Dist.), Academic Foundation Doctor Year 2
- S. E. Cavanagh, BSc, MBBS, PhD, Academic Foundation Doctor Year 2
- Y. Gelfer, BSc, MD, PhD, FRCS, Consultant Paediatric Orthopaedic Surgeon Trauma and Orthopaedics Department, St George's University Hospitals NHS Foundation Trust, London, UK; St George's University of London, London, UK.
- A. Russell, BSc (Hons), Advanced Physiotherapy Practitioner, Paediatric Physiotherapy Department, St George's University Hospitals NHS Foundation Trust, London, UK.
- A. Bridgens, BSc, MBBS, FRCS, Consultant Paediatric Orthopaedic Surgeon, Trauma and Orthopaedics Department, St George's University Hospitals NHS Foundation Trust, London, UK.

Author contributions:

- S. A. Hussain: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing.
- A. Russell: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Writing – review & editing.
- S. E. Cavanagh: Conceptualization, Formal analysis, Methodology, Visualization, Writing – review & editing.
- A. Bridgens: Investigation, Methodology, Resources, Supervision, Writing – review & editing.
- Y. Gelfer: Conceptualization, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing.

Funding statement:

- The authors received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement:

- The authors have no conflict of interests to declare.

Data sharing:

- The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

Acknowledgements:

- We would like to acknowledge and thank all the practitioners and clinicians involved in delivering Ponseti congenital talipes equinovarus (CTEV) delivery across our service for their patient-centred care.

Ethical review statement:

- Not applicable

Trial registration number:

- St George's Hospital, Registration number: AUDI003484.

Open access funding:

- The authors confirm the open access fee for this study was self-funded.

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