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Postoperative Protocols for Lower Extremity Free Flaps Reconstructions

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Abstract:
Background: Evidence for post-operative care of lower extremity free flap reconstruction (LEFF) varies and is yet to be standardized, despite established guidelines by the Orthopedic Association Standard for Trauma (BOAST-4). This study assesses post-operative protocols for LEFF clinical monitoring, warming, dangling, and compression in UK Major Trauma Centers (MTCs).
Methods: An online questionnaire was distributed to consultant leads of all UK adult MTCs. Data requested the existence of a standardized protocol, intensity and takeback of LEFF procedures and specific practices in clinical monitoring, warming, dangling, and compression. Analysis was performed in Excel.
Results: The survey was returned by 23 (79.3%) units and most (86.9%) had standardized LEFF monitoring protocols. Centers typically performed 4-8 surgeries monthly and on average had 2.7 salvageable LEFFs in 2022. Clinical monitoring was common (>92%) and included color, capillary refill and temperature assessment. Compression initiation varied with 45.5% starting after day 7 and 40.9%, between days 3-5. Continuous compression was favored (78.3%), using pillows (88.9%). Dangling protocols begin between days 3-7, for 5 minutes (52.2%) with frequencies of three to four times daily (25%-37.5%). The preferred tool for LEFF warming was the Bairhugger (82.6%) and the mean termination day for warming was 3.61.
Conclusion: The survey highlights the need for evidence-based and consensus in UK MTC protocols for LEFFs. We encourage ongoing research and collaborative efforts in creating an accepted protocol among MTCs that could be incorporated into the BOAST-4 guidelines for postoperative care standardization and improved patient outcomes.

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Postoperative Protocols for Lower Extremity Free Flap Reconstructions: Literature Review and A National Survey of the UK Major Trauma Centers

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Background

Free flap tissue transfer is an optimal method for reconstructing soft tissue defects due to cancer, trauma, or infection worldwide[1]. This procedure is prominent in plastic surgery and in cases of complex traumatic wounds, it may be the only alternative for limb salvage[2]. However, free flaps can have multiple complications, particularly those relating to intricate vessel anastomosis mechanisms, neural regulation, local and systemic mediators, and patient-dependent factors[3]. Although the effectiveness of separate procedures such as dangling or compression have been previously studied[4], there is no evidence on the preferential use of these individually or as a combination in United Kingdom (UK) Major Trauma Centers (MTCs). Additionally, despite the established guidelines for lower extremity free flap (LEFF) reconstruction by the British Orthopedic Association Standard for Trauma (BOAST-4), post-operative care has yet to be standardised[5]. Consequently, decisions regarding the choice of practice rely heavily on clinical judgement and thus variations between hospitals and individual surgeons exist.

Protocols for post-operative management of free flaps have been standardized for other anatomical sites, such as the head and neck[6] which has led to enhanced efficiency in healthcare delivery and patient safety. Standardization can also mitigate disparities in clinical management, improving standards of care, reducing errors and waste production, and enhancing clarity among multidisciplinary teams. Standardization and consistency of practices across MTCs for LEFF post-operative care can advance healthcare outcomes. [17].

Despite prior research in the UK during the past two decades and similar studies conducted in Canada and the United States[8-11], to our knowledge, no study exploring the postoperative care

of LEFFs in UK MTCs has taken place before. This study is the first to survey UK MTC post-operative care of LEFFs and elucidate the current trends in protocols and preferences for clinical monitoring, warming, dangling and compression.

Therefore, the aims of this study were firstly, to determine whether there are center-specific protocols or recommendations for the post-operative management of LEFFs in MTCs across the UK and secondly, to document the preferred methods and techniques employed for the post-operative management of LEFFs.

Methods

We designed a prospective audit of practices in post-operative lower limb free flap surgery. This survey is reported using the Consensus-Based Checklist for Reporting of Survey Studies (CROSS) checklist[12]. A questionnaire was built using the JISC online surveys tool, comprising of six sections and a total of 21 questions [Figure 1]. Responses were provided by participants in the form of a drop-down list, single answer questions, multiple choice questions and "free text" responses for qualitative assessment of supplementary information.

A pre-testing phase was conducted in our unit, involving three plastic surgeon trainees and consultants that did not participate in the questionnaire creation. Although they operated within the same department, the variability observed in their responses prompted us to refine the question specificity and clarity of the questionnaire by reducing "free text" responses. The final questionnaire is available in Appendix 1.

The questions for this survey were devised based on reviewing existing literature for the post-operative management of LEFFs. Consultants specializing in LEFF surgery within an adult UK MTCs were eligible for inclusion in this study. Conversely, consultants specializing in LEFF surgery in pediatric MTCs, working in non-MTC hospitals or not specializing in LEFF

procedures were excluded. The survey was shared with the consultants responsible for lower extremity free flaps across the 29 UK MTCs [Figure 2].

Participants were recruited through a convenience sampling approach, using the British Association of Plastic Surgeons' (BAPRAS) members directory. They were contacted via email and the survey was shared as a link. In cases where potential participants were unavailable, alternate contacts were sought, up to two attempts. For each participating department a single consultant deemed representative of the unit's prevailing practices was nominated. Multiple participation was prevented by contacting each consultant once at a time and allowing a timeframe of four weeks before contacting another.

As post-operative care LEFF practices vary between consultants and between departments, the aim of this study was to explore a consensus across the UK. The survey was available between February and June 2023. Ethical approval for conducting the survey was granted from The Royal London Hospital (registration number: 13072). Measures were implemented to ensure confidentiality and anonymity during result analysis and identifiers were systematically removed prior to data extraction. Results were analyzed on Microsoft Excel and are presented with narrative statistical analysis. Graphs and figures were generated using the JISC online surveys software.

Results

There were 23 respondents from the 29 surveyed units (response rate, 79.3 %) [Figure 2]. Of these, 20 had a standardized protocol for one or more aspects of LEFF monitoring.

General Practices (sections 1 and 2 of questionnaire)

Protocols for clinical monitoring were employed in 19 centers and in 18 for dangling. Additionally, most centers had protocols for handheld acoustic doppler, warming and elevation. Less than 7 centers used compression, 5 venous flow couplers, and none used laser

Doppler ultrasound for additional monitoring. Frequency of LEFF surgeries varied among centers, with 7 conducting 4-8 LEFF surgeries, 7 performing 2 surgeries, and 6 performing 4 surgeries monthly. Only 3 centers did more than 8 surgeries monthly. On average, LEFFs requiring take-back in each center during 2022 was 2.7.

Clinical Monitoring (section 3 of questionnaire)

As standard practice in clinical monitoring, nearly all centers use color assessment (22), capillary refill (22) and temperature (21) measurements. Other less popular options are doppler, turgor, urine output, flow coupler, adherence of graft, and contractility. Frequency trends of clinical monitoring are shown in Figure 3. Clinical monitoring is terminated after 5 days in over half centers (13) while 2 conclude at day 6, 5 at day 7 and 2 go beyond day 7.

Compression (section 4 of questionnaire)

Initiation of LEFF compression varied [Figure 4]. Most MTCs (18) prefer continuous compression and only 2 perform intermittent compression. In 3 centers alternative schedules are used. Furthermore, most (17) units do compression with elevation, using pillows (16), bed positioning (9), heel stand (4) or foot stools (1). Regarding the instruments used, most centers preferred Tubigrip (18), followed by compression garments (4) and less commonly Coban wrap, straps or adapting the approach based on patient and surgeon preferences. In 15 centers, compression is stopped based on patient parameters while in 6 it is stopped at week 6 and in 2 at week 4.

Dangling (section 5 of questionnaire)

Most centers begin dangling between days 3 and 7. The most frequent choice was Day 5 (7), followed by Day 4 (6) and Day 3 (5). Regarding duration of dangling, over half (12) continue for 5 mins and the rest have variable schedules. Frequency of dangling among MTCs was

also split between four times daily and other variable answers [Figure 5]. 7 centers opted to stop dangling on Day 7, 6 after Day 7 and only 2 stopped on day 5. The remaining 8 MTCs do not to have a “pre-specified” time. Compression in combination with dangling is used in 13 MTCs, 8 centers do not use compression and 2 do it occasionally.

Warming (section 6 of questionnaire)

Bairhugger is the most preferred tool for LEFF warming (19) and other tools included blanket (7) and simple dressing (4), often used in combination with the bairhugger. There is great variability in termination of warming, with the average day being 3.61 [Figure 6].

Discussion

Successful outcomes in free tissue transfer rely on the continuous flow of arterial blood and venous drainage through the open microvascular anastomosis, until new vasculature is established from the periphery[13]. Vascular compromise may result from venous thrombosis, arterial insufficiency, hematoma, or wound dehiscence, with venous insufficiency being the most common cause of flap failure. To prevent this, multiple postoperative monitoring methods have been developed and early recognition of potential complications is essential[14].

Clinical monitoring

Given the personalized nature of choosing clinical monitoring practices to assess flap success and the influence of observable factors such as color, we aimed to identify the preferred practices and those deemed most valuable among plastic surgeons, however these were not necessarily based on best practices. Karinja et al. noted that most surgeons opt for traditional monitoring methods due to their cost-effectiveness, accuracy, and easy availability, despite other methods like ultrasound detecting flap failure earlier. Thus, in our questionnaire, we enabled a multiple selection of different aspects of conventional monitoring and provided an “other” free-text option for newer techniques such as handheld doppler[15].

Free flap postoperative care has been an essential component because of the early reliance of free flaps for blood supply through the anastomosed vascular pedicle[14], and is therefore regarded as the gold standard for free flap monitoring in most institutions[16,17]. Therefore, close monitoring for indicators of vascular compromise has become a mainstay and the first 24 hours are considered the most crucial[14]. Though, the most effective approach for monitoring free flaps clinically, remains uncertain[18].

Present investigations do not delineate the superiority or inferiority of particular techniques within clinical monitoring, nor do they draw comparisons among them. Winterton et al. suggests that clinical judgment alone with a low threshold for intervention from experienced individuals can achieve high rates of operative success[19]. Despite the quality of clinical examination, differences in health professional training and experience can affect prompt recognition of potential issues[14,20]. A more objective tool for monitoring is the external Doppler ultrasound, which can further improve outcomes of clinical monitoring[17]. Success rates of above 97% have been reported in the literature where doppler and clinical examination are used as the sole method for flap monitoring[20].

Frequency trends show that in the majority of MTCs, clinical monitoring in the first 24 hours takes place every 30 min and increases to 1 hour over the next 24 hours. From days 2 to 5, 13 units do clinical monitoring every 2–4 hours. This coincides with literature recommendations of close observation of the free flaps in the first 72 hours post-operatively on an every 1-to-2-hour basis[21]. While Zoccali et al. suggest that in the first 48 hours, hourly flap monitoring should be compulsory and then can be reduced to four times daily[22]. Notably, location of monitoring (i.e. HDU vs normal hospital room) does not impact takeback/salvage of flaps[23].

The preferences of each MTC consultant regarding the termination of clinical monitoring are similar to the literature recommendations[24]. Furthermore, overcoming some of the limitations

of LEFF clinical monitoring and extending the period of monitoring beyond the post-operative stay may be the more newly adopted smartphone applications and telecommunication tools; allowing for similar sensitivity and specificity as clinical monitoring and presenting the advantage of being performed remotely[25].

Compression

Compression of the LEFF during dangling allows for venous and lymphatic return, as a result decreasing oedema and increasing perfusion. It is a low-cost and effective therapy for improving post-operative outcomes and quality of life of patients[26]. Various compression routines have been devised and initiation of compression varies[3,27]. Similarly, our survey showed that 45.5 % of units started after day 7 and 40.9 % started between days 3-5. Moreover, most MTCs favor continuous compression, while the literature suggests a gradual progression from intermittent to continuous compression as the flap integrates and as long as there are no signs of congestion and ischemia[3,29]. Kolbenschlag et al. observe that when dangling is performed with compression bandaging, oxygen saturations and blood flow in the free flap increase and overall pain and oedema formation are reduced[28]. In contrast, other studies suggest that compression versus no compression does not have any other clinical benefits[29,30]. Most MTCs prefer the use of Tubigrip for compression while others use compression garments or other tools, similar to what is reported in the literature[27]. Elevation of the LEFF is important in enhancing the venous and lymphatic return produced by compression[31]. Though less than three quarters of the MTCs perform elevation along with compression.

Dangling

Dangling is an important part of LEFF postoperative care as it can prevent oedema formation and venous congestion where new blood vessels have not yet been established[4] There is a

lack of consensus regarding the optimal timing and approach for initiating dangling protocols[3,32,33]. Several studies have shown that aggressive dangling protocols beginning as early as day 2 can improve functionality and potentially reduce risk for complications due to prolonged hospitalization without compromising patient safety or comfort[34]. Another study, with a smaller patient sample also noted that an early dangling protocol can be initiated with walking as early as the first postoperative day. Notably, there were no anastomotic failures or complications, and even patients in their 80s were able to ambulate with a walking frame on the initial postoperative day[35]. Collectively, these studies highlight the safety and efficacy of implementing an early dangling protocol by surgeons with minimal complications, as demonstrated in a recent systematic review[33].

Nevertheless, multiple studies still advocate for a later initiation period as their standard practice due to concerns of anastomotic leak and flap failure. For example, Ridgway et al. started dangling on post-operative day 7 and wrapping of the LEFF on day 14, though the patient sample was very low[30]. Similarly, our study demonstrates a significant variability in the commencement of dangling protocols, though most responses lie around day 5.Conventional dangling protocols typically begin after the fifth day, as animal studies have shown the establishment of a stable pseudo-intima by this time[36]. Therefore, variability and inconsistencies in starting dangling persist across countries and centres[34] and studies with a higher level of evidence are required to show if there is a clinically significant difference between starting dangling in post-operative days 3, 5 or later.

Frequency of dangling and whether extended periods of dependency could effectively stimulate angiogenesis or enhance collateralization within the flap are unclear. A systematic review by McGhee et al. shows variability of dangling regimes to maintain safe venous pressure throughout. They conclude with frequencies ranging from daily to hourly, from 3 to 8 days in length and with training sessions lasting 5 to 45 minutes[33]. Fufa et al. mention

dangling should be done for 5 minutes twice daily on day 5, followed by 10 minutes twice daily on day 6-7 increasing to dangling 3 times daily for 15 minutes for the last 2 weeks[32]. Rohde et al. suggested start dangling at 5 minutes twice a day and increase by 5 minutes per session per day or add an additional period of dangling per day until the patient is tolerating 30 minutes of dangling at least six times per day[8].

Furthermore, Henton et al. compared the flap's oxygenation during dangling noting increases in hemoglobin concentrations from day 1 after 5 minutes of dangling[37]. Kolbenschlag et al. noted quicker attainment of a plateau with a 13% increase in pre-dangling tissue hemoglobin levels. Additionally, the rise reduced from 55% on day 1 to 39% on day 3, and recovery times improved from 2.4 to 1.8 minutes over the training period[28]. Similar to scientific literature, in our survey, the majority of centers (52.2%) implement a 5-minute duration on day 1 for LEFF dangling though frequency of dangling was split with varying practices.

Furthermore, inconsistencies regarding the optimal duration of dangling also affect appropriate timings for its cessation. Henton et al. and Kolbenschlag et al. concluded that a 3-day training period may be sufficient for effective flap rehabilitation via measuring transcutaneous oxygen saturation[37,38]. However, this contrasts with practices in UK MTCs, most of which end dangling after Day 7.

Warming

Thermal regulation for flap success is well recognized and incorporated in standard post-operative care. As free flaps are separate from the temperature homeostasis of normal skin, prolonged LEFF hypothermia affects basic cellular functions that are important for the flap survival[39]. Warming can be achieved either through passive warming or active warming[40]. The Bairhugger is a preferred method for LEFF postoperative care[11] which coincides with our findings.

Limitations

Limitations of this study include the small sample size (23), with one consultant considered to be representative of a unit's practices and without accounting how long they had been working in that MTC. Furthermore, we did not capture whether consultants varied their protocol depending on the characteristics of each case and did not assess how likely surgeons would be to change their practice if higher-level evidence was available. Other sources of bias in our survey include social desirability bias, demand characteristics and acquiescence bias. As this survey provides a general picture of LEFF practices in UK MTCs, its findings may not be applicable to and relevant to other countries or the pediatric population.

Conclusion

This survey demonstrated lack of evidence, consensus and large variability in LEFF postoperative practices. Previous studies have attempted to analyze individual post-operative approaches, yet a lack of comparative data or a standardized protocol exists. This may be due to operative care practices varying based on surgeon preference, patient characteristics and hospital recommendations. Adding to this is the challenge of tailoring monitoring strategies to individual cases while considering established best practices. Nevertheless, absence of definitive evidence leaves uncertainty about whether specific methods or their combination are better or worse. As a result, selecting a procedure relies heavily on clinical judgement. This survey was not devised to guide clinical practice but rather to set new avenues for research, therefore we encourage the conduction of higher impact research on postoperative LEFF management in MTCs. Such research should encompass comprehensive evaluations of postoperative strategies considering their complications and outcomes as well as issues relating to their implementation. Following, we strongly recommend the collaborative development of an MTC-wide protocol grounded on current literature and systematic

reviews, ensuring a best-practice approach to care, in line with patient and surgeon preferences.

If this process proves successful, we recommend making changes and adding additional standardized techniques to the BOAST-4 guidelines. By doing this, we believe that the standardization of postoperative care for LEFF in MTCs across the UK will improve, leading to even higher success of free flaps and better restoration of lower extremity function.

Conflict of interest

The authors report no conflict of interest.

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Figure legends

Figure 1: The six sections of the questionnaire. The first two sections explored general practices in the post-operative care of LEFFs, including presence of a postoperative care protocol, the specific practices it covers, LEFF intensity and salvage frequency. The next sections (3-6) focus on specific aspects of clinical monitoring, compression, dangling and warming.

Figure 2: The 29 UK adult MTCs that were identified and contacted. In green are the 23 centers that responded to our survey and in red are the 6 that did not.

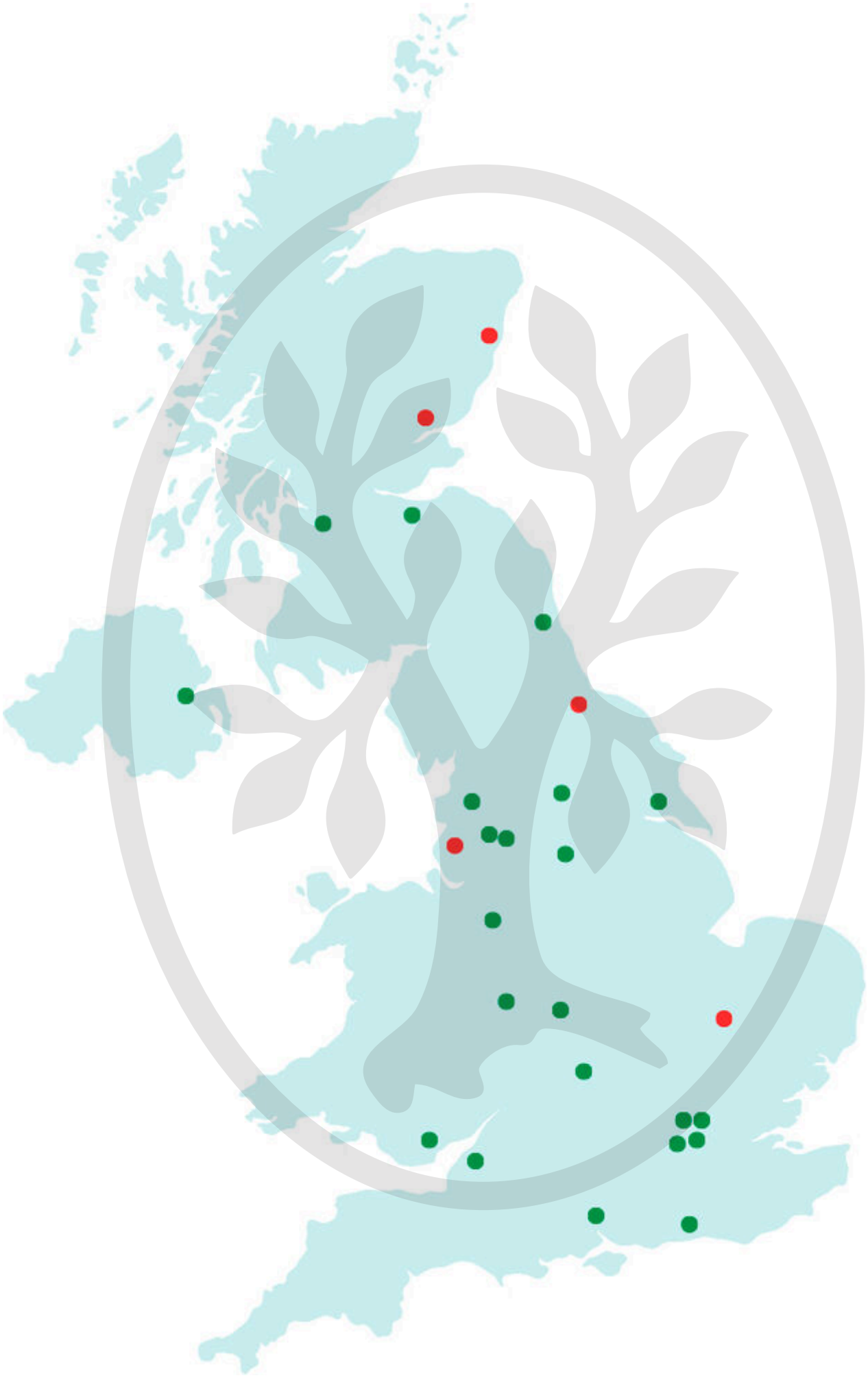
Figure 3: The distribution of the frequency of clinical monitoring of LEFF per 24-hour period. Frequency trends show that in the majority of MTCs (65.0 %), clinical monitoring in the first 24 h takes place every 30 min and increases to 1 hour over the next 24 hours (70 %). Finally, on postoperative day 2 until day 5, thirteen out of 23 units (57.0 %) do clinical monitoring every 2–4 hours, as seen in Figure 4.

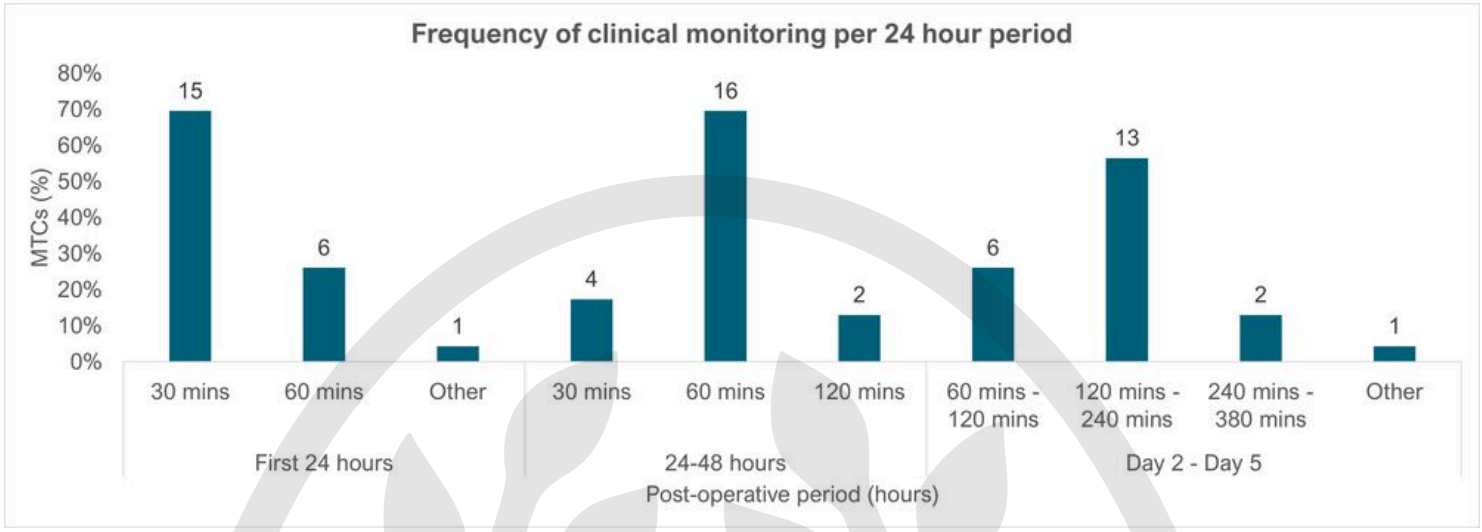
Figure 4: The distribution in the initiation of LEFF compression varied. More than half (n = 13, 56.5 %) centers start on or after day 7, while the remaining (n = 10, 43.5 %) start between days 3-5.

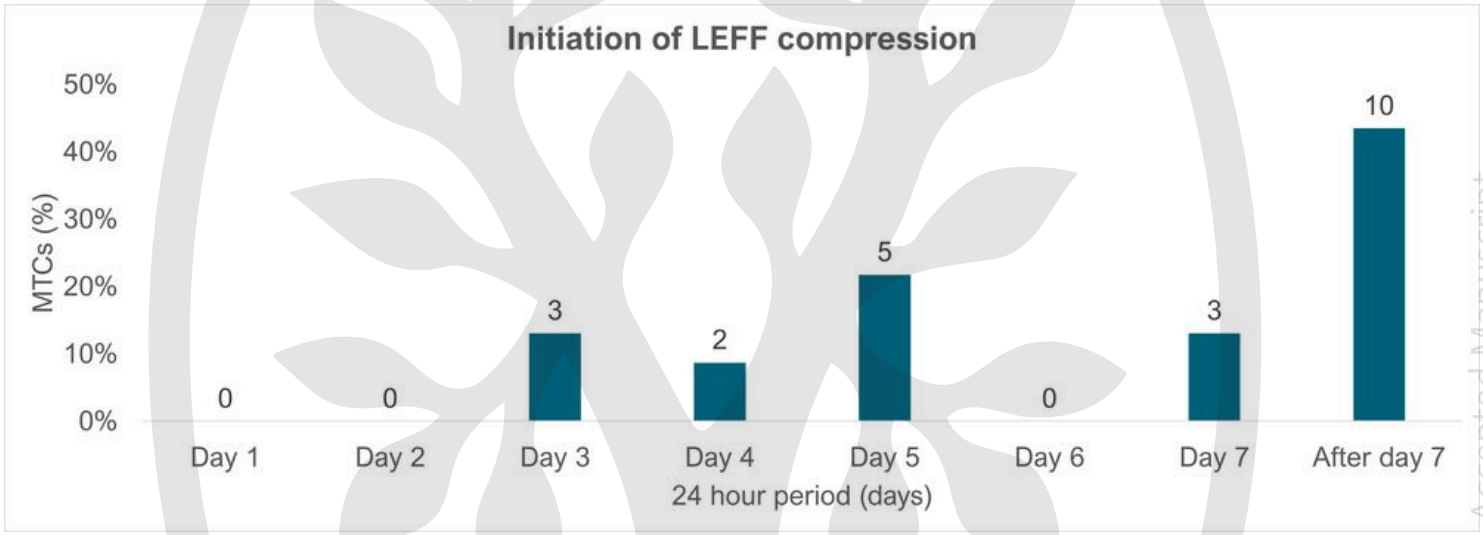
Figure 5: Frequency of dangling varied. Over half MTCs (n = 14, 60.9%) dangle between three-four times daily, while just one center (4.3%) dangles once daily and no centers dangle twice or five times daily. The remaining 8 (34.8%) respondents vary their practice based on patient parameters (3), opt for a progressive regime until mobilization is achieved (2) or dangle more aggressively from once an hour to six times daily (3).

Figure 6: The bar graph illustrates the percentage of "Termination of LEFF warming" occurrences over different 24-hour periods, spanning a week and beyond. The y-axis represents the "MTCs (%)" ranging from 0% to 30%, while the x-axis depicts the days, from

"Day 1" to "After day 7" and an additional category labeled "Other". The termination of warming varied greatly between hospitals and trusts. The highest termination rate was observed on Day 2, with approximately 25% and 6 occurrences. Both Day 4 and Day 5 witnessed similar termination rates, each standing at around 15% with 5 occurrences and no terminations were documented on Day 6 and after Day 7.







1 Post-operative LEFF protocols

- Presence of protocol?
- For which practices

2 LEFF frequency and take-backs

3 Clinical monitoring

- Initiation, frequency and termination
- Practices used

4 Compression

- Initiation and termination
- Intermittent vs continuous
- Concurrent elevation

5 Dangling

- Initiation, frequency and termination

6 Warming

- Termination
- Instruments used