Journal of Pediatric Endoscopic Surgery (2026) 8:93–99
https://doi.org/10.1007/s42804-026-00308-z

RESEARCH

Digital chest drain in paediatric surgical patients

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Received: 20 December 2025 / Revised: 9 March 2026 / Accepted: 19 March 2026 / Published online: 15 April 2026

Abstract

Purpose Chest drains used after thoracoscopic and open surgery traditionally rely on underwater drain (UWD). While Thopaz+ digital chest drain is NICE-recommended for adults, its usage in paediatric populations is underreported. This quality improvement project (QIP) evaluated the efficacy and safety of adopting Thopaz+in paediatric surgical patients.

Methods Thopaz+was introduced in the Paediatric surgery department. Retrospective data were collected for patients undergoing thoracic operations between 10/2022 and 07/2025, including demographics, chest drain indication, drain duration, and complications.

Results Of forty-nine patients (aged 1 day to 17 years; median age: 2.34 years, IQR 0.29–13.19), 55.10% ($N=27$) used Thopaz+and 44.90% ($N=22$) used UWD. Thopaz+ group was significantly older (median 12.2 years-old (2.3, 15.1), 95% CI: 6.7–12.0) and heavier (median 44 kg (16,55), 95% CI: 29–47) than UWD group (median 0.3years-old (0.0, 1.9), 95% CI: 0.73–5.6; median 12 kg (9,16), 95% CI: 11–26), reflecting absence of Thopaz+ adoption for neonates within the trust ($p<0.001$ for age; $p=0.002$ for weight). Thopaz+ trended towards a shorter chest drainage duration, with a median of 2 days (1.0, 6.0; 95% CI 2.1–5.9), vs. median of 3.5 days (2.0, 7.0; 95% CI 1.2–16) with UWD, although not statistically different ($p=0.088$). Complication rate was not significantly different: 22.2% ($N=6/27$; 95% CI 9.4–43) with Thopaz+vs. 9.1% ($N=2/22$; 95% CI 1.6–31) with UWD. Satisfaction survey heavily favoured Thopaz+.

Conclusion This study shows Thopaz+can be safely and feasibly implemented in paediatric surgical practice. Larger, multicentre studies are needed to define the cost-effectiveness and develop paediatric clinical protocol.

Keywords Digital chest drainage · Thopaz · Paediatric thoracic surgery · Perioperative patient safety

Introduction

Chest drains are a fundamental component of the postoperative management following thoracic surgery in children. It is indicated to remove air, blood, fluid, pus or lymphatic fluid from pleural or mediastinal spaces, helping to re-expand lungs and prevent postoperative complications. In the current practice in the United Kingdom (UK) and worldwide, underwater sealed drains(UWD) have traditionally been used as the standard practice. UWD systems remove air or fluid from the pleural cavity while preventing its backflow of fluid and water into the pleural space. This enables lung expansion and restoration of negative pressure in the thoracic cavity. However, several challenges are associated with UWDs: (1) unsafe nature due to reflux of contents back into pleural space, (2) subjective interpretation of air leaks and inter-observer variability, (3) increased nursing and clinician workload, (4) patients' immobility, and (5) unreliable and inefficient suction.

Digital chest drains have been in use from 2010 [1]. Growing evidence on the benefit in adults have led to their adoption across many thoracic departments. One such digital chest drain system is Thopaz+ digital chest drain [2]. In 2022, The National Institute of Health and Care Excellence(NICE) recommended Thopaz+ digital chest drain usage in thoracic care, providing benefits such as reduced drainage duration, shorter hospital stay, and improved patient safety [3, 4]. Thopaz+has benefits of continuous monitoring of intrathoracic pressure and air leak dynamics, offering enhanced safety and objectivity compared with UWD systems. NICE

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identified 13 clinical studies as the evidence supporting the use of the Thopaz+ digital chest drain system and its advantages. Of these, only a single study is based on a paediatric population [5], while the remaining 12 studies were conducted in adult patients; highlighting a substantial evidence gap in children. Only one paediatric study was available to be included in that analysis. This was a non-comparative study, describing initial experience by Costa et al. [5], who evaluated digital chest drain in 11 children and reported a mean hospital stay of 4.9 +/- 2.6 days, a mean duration of drainage of 2.5+/- 0.7days and postoperative complications in two patients (18%) Although the evidence base in children has increased since then, it is still limited.

The adoption of Thopaz+ digital chest drain system aligns with local, regional, and national priorities to improve patient safety, clinical efficiency, and adoption of evidence-based digital technologies in healthcare. Locally, this change supports the local hospital Trust's strategic goals to improve patient and family experience in paediatric surgical settings, by reducing variation in chest drain management, enhancing safe, effective care through digital innovation. At a regional level, it aligns with Integrated Care System (ICS) goals in NHS England to streamline care pathways, improve outcomes across surgical and post-operative care. The digital system allows real-time data and patient journey display, which facilitates sharing information across hospitals in different trusts when joint care or transfer is required for patients with chest drains. Nationally, adoption aligns with the NHS 10-year Plan for digital innovation and patient safety, supporting government targets for reducing hospital stays and improving elective recovery [6].

Materials and methods

A Quality Improvement Project (QIP) was conducted at our tertiary paediatric surgery department. The aim was to evaluate and assess the efficacy and safety in adopting Thopaz+ digital chest drain in paediatric surgical patients. A retrospective review was conducted of patients who underwent thoracic surgery between October 2022 and July 2025. Chest drains were placed after thoracoscopic or open procedures, with hourly monitoring by nursing staff and clinicians in postoperative drain care. Data collected include age, weight, surgical approach, underlying diagnosis, type of chest drainage system used, duration of chest drainage and postoperative complications. Statistical analyses included Wilcoxon rank sum test, Pearson's Chi-squared test, Fisher's exact test to compare drainage duration, complication rates and patient demographic characteristics between Thopaz + and UWD groups.

A questionnaire was circulated to staff members to explore clinicians' experience with Thopaz+ intervention. Structured questionnaires were used to collect feedback from medical and nursing staff over a three-week period. The questions in the questionnaire explored (1) staff satisfaction with each drainage system, (2) perceived patient safety, (3) ease of use in clinical practice, (4) preference between Thopaz + and UWD, (5) reasons for preference and (6) suggestions for improving chest drain management. The questionnaire used for survey is illustrated in the Supplementary Material. Any paediatric surgery ward-based staffs present during the survey period were eligible to participate and it was undertaken with those who voluntarily agreed to share their experience; 11 of 16 (response rate of 69%) invited staff members completed the paper questionnaires. 11 replies were obtained from 4 doctors and 7 nurses.

Postoperative monitoring of patients managed with the chest drains was conducted 1 hourly clinical assessment by trained nursing staff, by reviewing of digital air leak measurements and drainage volumes, and through doctor's ward round, considering radiographic evaluation when clinically indicated. Criteria for drain removal included the following:

- Fluid drainage < 50mls in 24 h.
- No ongoing air leak or bubbling over 24 h.
- Indication for insertion has resolved (e.g. lung fully re-expanded).

The ultimate decision from the medical team would be made on this basis, considering the original indication for the chest drain, and overall clinical stability.

Results

This study comprised 49 patients aged from 1 day to 17 years (median age 2.34 years, IQR 0.29–13.19), including 14 female and 35 male patients. Diagnosis at operation of the patients is illustrated in Fig. 1. The postoperative stay ranged from 1 to 77 days, with a mean duration of 16.80 days. Thopaz+ digital chest drains were used in 27 patients (55.10%), and UWDs were used in 22 patients (44.90%). Thoracoscopic surgery was performed in 69.4% of cases.

The age distribution of patients in the Thopaz and UWD groups is summarised in Fig. 2. The median age in the Thopaz+ group was 12.2 years-old (IQR 2.3–15.1), whereas the UWD group had a markedly lower median age of 0.3 years-old (IQR 0.0-1.9). This difference was statistically significant (95% CI: Thopaz 6.7–12 years-old vs. UWD 0.73–5.6 years-old, $p < 0.001$). This reflects current hospital practice during the study period, during which Thopaz + had not yet been adopted for routine neonatal use. Within the Thopaz+

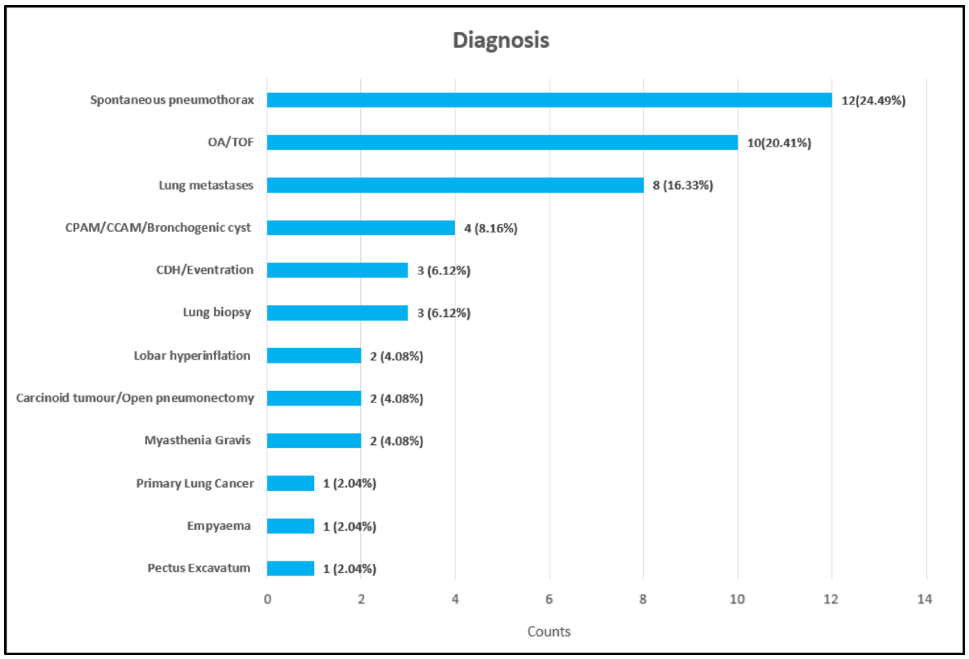


Fig. 1 Diagnosis. Operative diagnosis in the study are summarised. Absolute patient numbers are shown and corresponding percentages in brackets

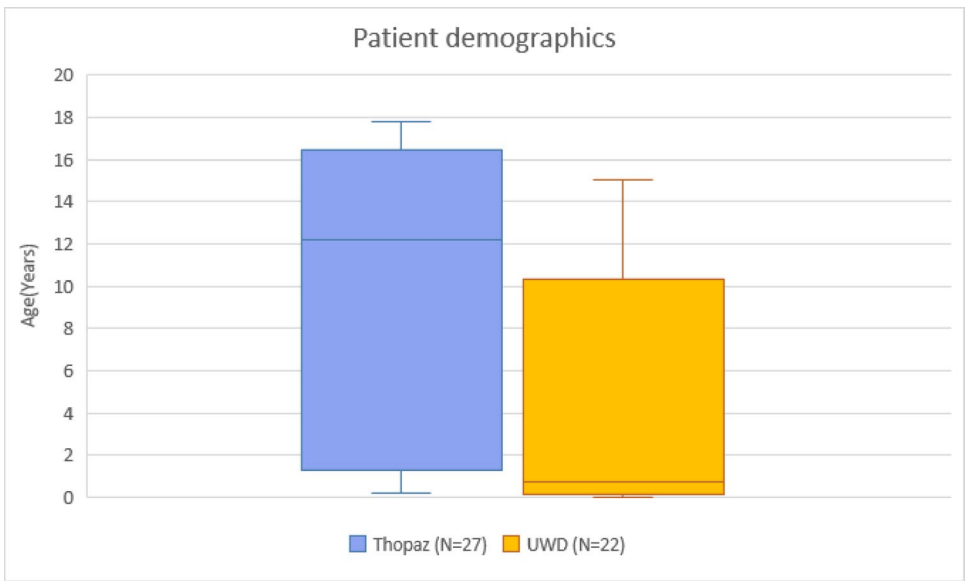
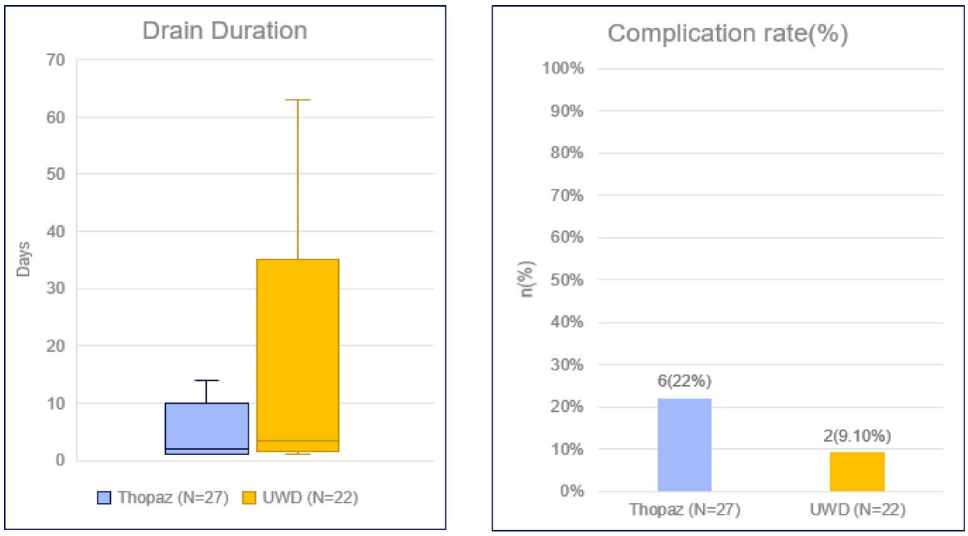


Fig. 2 Patient demographics (Age: Years). Box-and-Whisker plot of patient demographics between Thopaz + and underwater drain (UWD). Boxes represent the interquartile range, the horizontal line shows the median value, and whiskers show the range

group, 63% (17 of 27 patients) had the application of suction. The use of suction was independently determined by the clinical need of the patient and surgeon's preference. Similarly, the median weight differed significantly between groups. The median weight of patients in the Thopaz+ group was 44 kg (IQR 16, 55; 95% CI: 29–47), compared with 12 kg (IQR 9, 16; 95% CI: 11–26) in the UWD group ($p = 0.002$).

Median drainage duration (Fig. 3a) in the Thopaz+ group was a median of 2 days (IQR, 1.0–6.0), with a 95% confidence interval (95% CI) ranging from 2.1 to 5.9. In comparison, UWD group was of 3.5 days (IQR, 2.0–7.0) and a 95% CI of 1.2 to 16.0. However, this difference did not reach statistical significance, with p value of 0.088. Complication rates were comparable between the two groups. Complications occurred in 6 patients (22%) in the Thopaz+ group and 2 patients (9.1%) in UWD group (Fig. 3b), with overlapping 95% confidence intervals (9.4%-43% vs. 1.6%-31%; p value of 0.30). Documented complications included recurrent pneumothorax, blocked drains, prolonged air leaks and the need for a second drain. One patient died due to underlying disease rather than drain-related complications, and one case a 'complication' was noted but was not further specified.

Staff experience and feedback were obtained through the circulation of questionnaire: 11 replies were obtained from



3a. Drain duration(Days). 3b. Complication rate(%)

Fig. 3 Drain duration (**3a**) Box-and-Whisker plot of patient chest drain duration between Thopaz+and underwater drain (UWD). Boxes represent the interquartile range, the horizontal line shows the median value, and whiskers show the range. Complication Rate (**3b**) Overall complication rates for Thopaz+ drain and UWD system are illustrated as percentages in bar charts

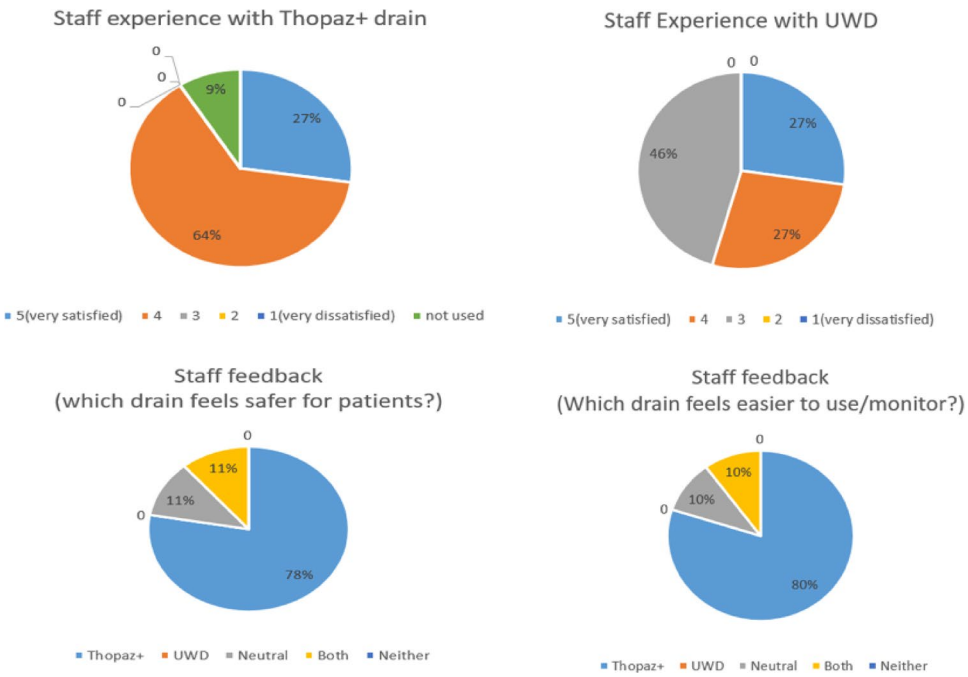


Fig. 4 Staff feedback. Staff experience and satisfaction were evaluated through the questionnaire. Pie charts illustrate staff experience ratings from 1(very dissatisfied)-5 (very satisfied)

4 doctors and 7 nurses (Fig. 4). Overall, satisfaction with Thopaz+ drain was high, with 91% of staff members reporting satisfaction (ratings of 4 or 5), including 27% who were very satisfied, and only 9% reported dissatisfaction. In contrast, satisfaction with UWD was lower and more variable, with 27% rating 4 or 5 respectively, and 46% reported dissatisfaction. When asked which drain felt safer for patients, the majority of staff favoured Thopaz+ (78%), while 11% preferred UWD, and 11% were neutral. Similarly, 80% of staff members reported that Thopaz+was easier to use and monitor, compared with 10% favouring UWD and 10% reporting neutral.

When staff were surveyed regarding their preference between Thopaz+ digital drain and UWD, out of 11 respondents, 8 staff members (72.73%) expressed preference for Thopaz+. In contrast, only 1 staff member (9.09%) preferred UWD, while 2 respondents (18.18%) indicated they valued both systems equally.

Discussion

There is limited experience with digital chest drain system in children, with a significant evidence gap in the literature. This descriptive quality improvement project addresses an

important evidence gap in paediatric thoracic surgery and provides valuable real-world implementation insights into the use of Thopaz+ digital chest drains. This descriptive data contributes some experience and evidence to support the feasibility and safety of Thopaz+in paediatric thoracic surgery. Though the numbers are small, its introduction supports that with further evaluation, data on outcome will provide evidence of further clinical benefit in children. This would be mirroring the evidence in the adult practice, but this assumption cannot just be extrapolated, and the evidence should be researched and developed.

Existing literature on the use of digital chest drain systems in paediatric populations remains significantly limited. As early as 2016 a report on the early experience of digital chest drain in children and reported its safe introduction [5], yet, much of the existing evidence is extrapolated from adult studies, which serves as indirect evidence rather than primary paediatric data. For instance, although Alam et al. (2020) reported that Thopaz+was associated with shorter tube duration and hospital stays, their cohort of 100 patients were children and adults [7]. Their findings demonstrated that Thopaz+use was associated with a shorter duration of chest tube placement, reduced length of hospital stay and lower complication rates compared with conventional chest drain. Also, their study was limited to patients with empyema thoracis undergoing decortication. No elective resections were included. One consecutive observational study by Pérez-Egido et al. (2018) also focused on the outcome of radiology exposure. They reported that Thopaz+ provided more objective measurement of air leakage, shorter chest tube duration, and decrease of the number of postoperative radiographs in 13 patients following pulmonary resection compared to conventional chest drain [8]. Frediani et al. (2023) retrospectively demonstrated a shorter duration of chest drain use of up to six days in a pure paediatric population, with need for fewer chest x-rays [9]. Collectively, these studies highlight the potential benefits of Thopaz+in younger patients while underscoring the need for further paediatric research to support wider clinical adoption.

Our descriptive quality improvement project performed with a wide range of thoracic operations in a pure paediatric setting. There were confounding factors affecting its interpretation and there was no statistical difference in duration of drainage, but there was a trend toward shorter chest drain duration with Thopaz+. This aligns to this existing literature, and supports the benefit that comes with the more precise monitoring, and consistent suction delivery with digital chest drain compared to traditional drains. The hypothesis is that the objective data provided by the digital drain allows earlier cessation of the drain with good clinical outcome. On looking at all the evidence quoted in the paediatric literature to date, this benefit (averaged between studies) ranges from 2 to 3 days less of chest drain use. With this being the most likely limiting factor for discharge, this translates to both a substantial benefit in patient outcome and hospital economy [3, 4].

Staff feedback supports the objectivity, better staff experience and clinical utility of the Thopaz+, particularly in relation to patient safety, mobility, and data-driven decision making. Staff members perceived Thopaz+ improved patient comfort and overall recovery, mentioning easier patients' mobility with its portable design and no need for wall suction. From a safety and nursing perspective, Thopaz+was consistently mentioned as easier to read and monitor, allowing for more objective and efficient assessment which nurses favoured Thopaz+ more over UWDs. Nursing staff also reported ergonomic benefits with Thopaz+, noting that its portable and remote monitoring design reduced physical strain during the patient care, improving nursing workflow. As an example, because it does not need to be on the floor and can be at patient or eye level, nurses who have mobility issues also found Thopaz+ much easier to use and monitor. Importantly, from a medical perspective, the objective, real-time digital data generated by Thopaz+ enables more accurate assessment of air leak and drainage trends. Figure 5 is an example of a patient journey with an empyema, where the air leak (blue line) can be definitely seen to stop, and therefore the cessation of any bronchopleural fistula can be defined. Such digital informatics supports consistent data collection and more informed clinical decision making compared with UWDs: this was frequently mentioned in senior doctors' responses.

Nevertheless, some limitations need to be acknowledged. This was a retrospective single-centre study with a small sample size, which limits generalisability and statistical power. There are several confounding factors, including the fact that choice of Thopaz+ usage relied on surgeons' decision making and preference during the study period, thereby introducing potential selection bias that could have impacted the outcomes described in this study. This was further confounded by the exclusion of neonates to the Thopaz+ system during the early adoption during this quality improvement project. This resulted in the Thopaz+ group being significantly older than UWD. These fundamental disparities in age and weight could preclude valid outcome comparisons between the two groups in this study. Having established the safety and efficacy of digital drainage these confounding factors should be reduced in further analysis of the outcome in further studies.

Also, the adoption of the Thopaz+ system may have been affected by the learning curve associated with its introduction. Medical and nursing staffs may require time to become proficient in monitoring digital chest drain, integrating it into established postoperative workflows. Staff survey

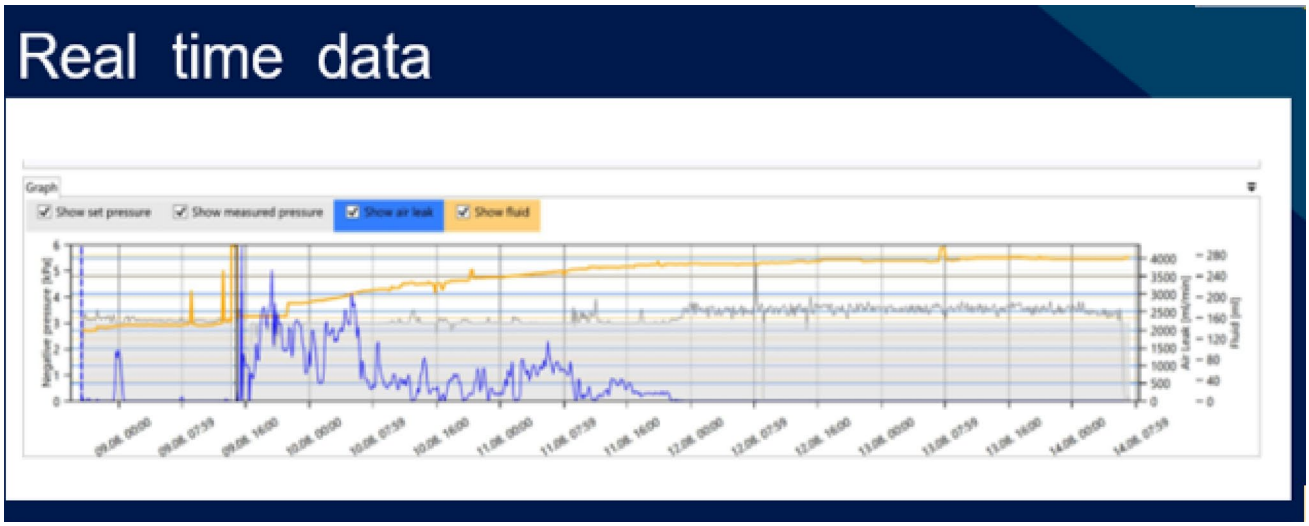


Fig. 5 Real time Thopaz+ monitoring data. This shows an example of real-time Thopaz+ digital monitoring of a patient journey with an empyema. This demonstrates continuous measurement of air leak (blue line in mls/min) and fluid (yellow line total volume in mls) over time. The grey bar indicates the set negative drain suction pressure, and the black line the measured intrapleural pressure in kPa

revealed that the need for more structured staff training as most frequently mentioned area that need for improvement. Staff members emphasised the need for regular study days, in-depth training about protocol, junior doctor training for familiarity as the suggestion for improvement in maximising the safe and effective use of Thopaz+. Variability in staff familiarity using digital chest drain could therefore have contributed to results. Most of current evidence regarding this learning curve in digital chest drain is based on adult data, which serves as indirect evidence for the paediatric settings. Pompili et al. (2011) indicates the learning curve for using novel device, such as electronic chest drainage system typically slopes down only after an initial phase of approximately 40 cases [10]. The study suggested once this threshold is surpassed and the staff gained sufficient confidence in new electronic chest drainage, the maximum benefits- such as significantly reduced chest drain duration and shorter hospital stays, financial cost benefits – become fully evident [10]. Therefore, the data from this descriptive quality improvement project with feasibility and implementation outcomes, could be used to provide support for the introduction of digital chest drains in paediatrics, with good prospective studies providing more substantial evidence of benefit. The development of protocols using the digital information provided, to further aid decision making in the paediatric population is also needed.

Current evidence supporting Thopaz+use is largely derived from adult studies, and extrapolation of these findings to paediatric patients should be undertaken with caution given differences between adult and paediatric patients. Consequently, paediatric-specific data remain limited, and single-centre quality improvement findings may not be generalizable. Further evaluation is therefore warranted to better define feasibility, safety, and implementation outcomes across a broader paediatric surgical population and to support the development of age-appropriate, evidence-based guidance for digital chest drainage use in children.

Conclusion

There is limited experience with digital chest drain system in children, with a significant evidence gap in the literature. This quality improvement project demonstrates that implementation of the Thopaz+ digital chest drainage system in paediatric surgical practice is safe and feasible and can be integrated into routine clinical workflows. With staff training, the feedback received support real-world adoption can be promoted in paediatric practice, with paediatric specific protocol development.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42804-026-00308-z.

Author contributions H.Y wrote the original draft and this was reviewed and edited by M.M for the final manuscript.H.Y prepared Figs. 1, 2, 3, 4 and 5, which was reviewed by M.M. All authors reviewed and approved the manuscript. 1. Conceptualization: Merrill McHoney, 2. Methodology: Heewon Yoon, Merrill McHoney, 3. Formal analysis and investigation: Heewon Yoon, 4. Writing-original draft preparation: Heewon Yoon, 5. Writing-review and editing: Heewon Yoon, Merrill McHoney, 6. Funding acquisition: N/A, 7. Resources: N/A, 8. Supervision: Merrill McHoney.

Funding The authors did not receive support from any organisation for the submitted work.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no potential conflicts of interests with respect to the research, authorship, and/or publication of this article.

Ethical approval Ethical approval was not required for reporting individual anonymised data for a quality improvement project following the local NHS Hospital Trust policy.

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