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Patient Experience with Electronic Versus Conventional Chest Drainage After Thoracic Surgery: A Prospective Observational Cohort Study

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Simple Summary

After lung surgery, patients are fitted with a chest drain that stays in place for several days. The drain is attached to a device that collects fluid and air from the chest. Two kinds of device are commonly used: a conventional device, and an electronic device that measures air leak automatically. Most research has compared these devices by looking at how long the drain stays in or how long patients remain in hospital. Far less is known about what patients themselves experience whilst fitted with one or the other. We asked 84 patients, most of whom had been operated on for lung cancer, how comfortable they felt, how easily they could move around, and how well they slept. Overall experience was similar with both devices, but patients with the electronic one moved more easily and were less disturbed at night.

Abstract

Background/Objectives: Chest drainage is a central element of postoperative management after lung resection and the main determinant of length of stay, yet the comparison between electronic and conventional systems has been built almost entirely on air-leak quantification and drainage duration, with little attention paid to what patients themselves experience. We aimed to compare patient experience with electronic (ETD) versus conventional dry-seal (CTD) chest drainage using patient-reported outcome measures (PROMs). Methods: This was a single-centre prospective observational cohort study carried out in a high-volume thoracic surgery unit (December 2025–March 2026). The primary outcome was the Global Experience Index (GEI; comfort, functional interference, perceived safety and overall satisfaction; 0–10 NRS). Secondary outcomes included sleep-disturbing factors (Carrera-Hernández nine-item questionnaire), perceived autonomy, mobility with the device (Pompili scale), and willingness to reuse the same system. All instruments were administered at drain removal in 84 patients undergoing lung resection (42 per group). Results: The GEI did not reach statistical significance (mean difference 0.57; 95% CI −0.20 to 1.32; $p = 0.246$; d = 0.31), although all four domains favoured ETD.

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The Pompili scale was the only instrument to reach significance (difference 0.31; 95% CI 0.05 to 0.54; $p = 0.026$; d = 0.51), with the largest effect on night-time comfort ($p = 0.013$; d = 0.57). Interference from monitor and alarm noise (item 2 of the sleep questionnaire) was also significantly lower with ETD (difference −1.31; 95% CI −2.32 to −0.30; $p = 0.032$; d = 0.53). Conclusions: ETD did not demonstrate statistically significant superiority in overall patient experience, but was consistently associated with better mobility and lower interference with night-time rest, domains of direct relevance to enhanced recovery protocols in thoracic surgery that warrant confirmation in adequately powered studies.

Keywords: chest tubes; patient-reported outcome measures; patient satisfaction; thoracic surgery; sleep; enhanced recovery after surgery; lung cancer

1. Introduction

Postoperative chest drainage is a central element of surgical management after lung resection. The majority of these procedures are performed as treatment for malignant disease, and the patient's functional condition at discharge conditions the subsequent oncological pathway, including tolerance of adjuvant treatment. Its handling determines not only the length of hospital stay, of which it is the main predictor [1–3], but also the degree of postoperative pain, respiratory functional recovery, and patient adherence to early rehabilitation protocols [4]. Two main types of system coexist in clinical practice: conventional analogue tube drainage (CTD), widely used for its simplicity and low cost, and electronic tube drainage (ETD). Conventional systems rely on subjective visual interpretation of the air leak, which generates considerable interobserver variability and introduces uncertainty into clinical decision-making [5]. Electronic systems, by contrast, provide a continuous and objective record of intrapleural pressure and air leak, thereby reducing that variability. Since the work of Cerfolio [6] and the multicentre trial by Pompili et al. [7], the evidence has consolidated the advantages of ETD in terms of shorter drainage time and reduced hospital stay. The most recent meta-analysis, by Embalabala et al. [8], pooling 14 randomised clinical trials, confirms a mean difference in length of stay of −1.40 days (95% CI −2.20 to −0.60) in favour of digital systems, consistent with the earlier meta-analysis by Wang et al. [9].

Research in this field has nevertheless paid little attention to an equally relevant dimension: the patient's subjective experience while carrying the drain. This experience, captured through standardised instruments known as PROMs (patient-reported outcome measures) and PREMs (patient-reported experience measures), is now recognised as a clinical outcome of the first order, comparable to traditional objective outcomes [10]. Evidence on the comparative experience of the two systems nonetheless remains scarce, methodologically heterogeneous, and discordant: Bertolaccini et al. reported higher patient satisfaction with ETD [11], Cerfolio found no significant differences in perceived mobility [6], and the trial by Pompili et al. yielded mixed results depending on the item assessed [7]. The meta-analysis by Embalabala et al. identified only three trials that assessed patient satisfaction, with discordant results and without instruments cross-validated for this specific clinical context [8]. Recent reviews of chest tube management after lung resection converge on the same conclusion: multiple strategies coexist, and the evidence supporting any of them remains limited and inconsistent [12,13].

Within enhanced recovery programmes in thoracic surgery, where early mobilisation, rest, and wellbeing during admission are explicit care objectives, rigorous evidence on the comparative experience of the two systems is directly relevant to clinical decision-making [14]. Early mobilisation is a cornerstone of these protocols after lung resection,

and the drainage device is the main physical obstacle to this. The present study evaluates that experience using complementary patient-reported instruments [15–17], with the aim of determining whether the use of ETD is associated with a better patient experience than CTD during the immediate postoperative period in thoracic surgery.

2. Materials and Methods

2.1. Study Design and Setting

This was a single-centre, prospective, observational, comparative cohort study conducted in the Department of Thoracic Surgery of the Hospital Clínico Universitario de Valladolid between December 2025 and March 2026. Allocation to drainage system was determined by device availability and the usual practice of the responsible surgeon, without formal randomisation, thereby reflecting real-world clinical conditions.

2.2. Participants

We included patients older than 18 years undergoing anatomical lung resection or another thoracic procedure requiring a postoperative pleural drain, who were able to complete questionnaires in Spanish and who provided written informed consent. We excluded patients undergoing pneumonectomy, those requiring prolonged mechanical ventilation (>24 h), those with severe cognitive impairment or a language barrier, and those requiring urgent reoperation within the first 24 h. Although the protocol allowed the inclusion of other thoracic procedures requiring pleural drainage, all patients finally included underwent lung resection. Of the 84 patients analysed, 65 (77.4%) were operated on for an oncological indication, 47 (56.0%) for primary lung cancer and 18 (21.4%) for pulmonary metastases. Preoperative pulmonary function testing included FEV1 in all patients. DLCO was additionally available in 80 patients; in the 4 remaining cases, all of whom underwent non-anatomical resection for benign disease, preoperative assessment was limited to spirometry.

2.3. Exposure and Outcomes

The exposure variable was the type of drainage system (ETD, Thopaz®, Medela AG, Baar, Switzerland; versus CTD, Pleur-evac®, Teleflex Inc., Wayne, PA, USA). The primary outcome was the Global Experience Index (GEI), a four-domain questionnaire (comfort, functional interference, perceived safety, and overall satisfaction) scored on a 0–10 numerical rating scale, with higher scores indicating a better experience [15,16] (see Supplementary Materials). The GEI was computed as the unweighted arithmetic mean of its four domains, so that the composite retains the original 0–10 range; no domain weighting was applied. Secondary outcomes were sleep-disturbing factors during night-time rest, measured with the nine-item questionnaire developed by Carrera-Hernández et al. [17] and scored on a 0–10 graphic rating scale per item, with higher scores indicating greater interference with sleep; perceived autonomy (4-point Likert scale); mobility with the device, measured with the Pompili scale (8 items on a 5-point Likert scale, with higher scores indicating better mobility) [7]; and willingness to use the same system again (5-point Likert scale). Covariates were age, sex, type of procedure, and surgical approach. All instruments were administered at the time of drain removal.

The choice of the sleep-disturbing factors questionnaire over instruments of global sleep perception, such as the Richards-Campbell Sleep Questionnaire [18], responds to the objective of the study: the aim is not to characterise sleep quality in absolute terms, but to identify the extent to which the drainage system specifically contributes to the disruption of night-time rest relative to other concurrent factors of the postoperative environment. Instruments of global sleep perception yield a single score that does not allow the

disturbance to be attributed to a specific cause, whereas this questionnaire disaggregates the factors described in the literature and includes an item specifically addressing discomfort from drains and cables, directly related to the exposure variable of this study. Two adaptations were introduced with respect to the original instrument: each item was scored on a 0–10 graphic rating scale instead of the original 0–100 mm visual analogue scale, and a mean of items 1–8 was computed as a summary measure, which does not exist in the original instrument, in which each factor is interpreted separately in qualitative bands. Item 9, an open-ended question, was not included in the quantitative analysis.

Chest drainage was managed according to the unit's ERAS protocol, which was uniform for all patients irrespective of the drainage system used. A single chest drain was placed in all cases. Suction was applied during the first 24 postoperative hours; thereafter, if the lung remained fully expanded, suction was discontinued. The drain was removed in the absence of air leak and with a fluid output below 450 mL in 24 h, in line with ERAS Society and ESTS recommendations [14,19]. Minimally invasive procedures were performed through a two-port approach, and analgesia was provided by epidural catheter. Preoperative education, early mobilisation, and respiratory physiotherapy were applied uniformly as components of the same protocol.

2.4. Sample Size

The sample size was calculated for a two-sided comparison of means between two independent groups, with $\alpha = 0.05$, 80% power and a minimum clinically relevant difference of 1 point in the GEI. Assuming a standard deviation of 2 points, this yielded 63 patients per group, rounded to 64. An interim variability analysis, performed at 50% of recruitment and restricted to the dispersion of the primary variable without examining between-group differences, showed a standard deviation of approximately 1.6 points. Recalculation with this value, keeping α, power, and the minimum clinically relevant difference unchanged, yielded 40 patients per group. Recruitment nevertheless continued until the end of the predefined study period, so that 84 patients (42 per group) were finally analysed, slightly exceeding the adjusted target without modifying the planned analysis.

2.5. Statistical Analysis

Analyses were performed with SPSS® Statistics v27.0 (IBM Corp., Armonk, NY, USA) and R v4.5.1 (R Foundation for Statistical Computing, Vienna, Austria). Normality was assessed with the Shapiro–Wilk test. Non-normally distributed continuous variables were compared with the Mann–Whitney U test and normally distributed variables with Student's t test. Categorical variables were analysed with the chi-square test or Fisher's exact test. Mean differences with 95% confidence intervals were calculated (bootstrap for non-parametric variables, analytical for parametric variables), together with effect sizes expressed as Cohen's d. Baseline comparability between groups was assessed with the same tests. The analysis was exploratory in nature and no correction for multiple comparisons was applied; accordingly, secondary outcomes were reported as hypothesis-generating. Given the baseline comparability between groups across all covariates assessed, unadjusted between-group comparisons were performed. Missing data were handled as follows: composite scores were computed only for patients with all constituent items available (complete-case analysis), whereas individual items were analysed using all available data. Missing values corresponded to isolated, non-systematic omissions when completing the questionnaires, and no imputation strategy was considered justified.

3. Results

A total of 85 patients were enrolled. The analysis was performed on 84 of them (42 per group), after excluding 1 patient who was transferred to another centre with the drain

still in place and for whom no data were available at the time of removal. The groups were comparable across all baseline variables analysed, including preoperative pulmonary function and comorbidity burden (Table 1). The participant flow diagram is shown in Figure 1.

Table 1. Baseline comparability between groups (N = 84).

Variable	CTD (N = 42)	ETD (N = 42)	*p*
Male sex, *n* (%)	20 (47.6)	23 (54.8)	0.513
Oncological indication, *n* (%)	31 (73.8)	34 (81.0)	0.434
Primary lung cancer	21 (50.0)	26 (61.9)	
Pulmonary metastases	10 (23.8)	8 (19.0)	
Major resection, *n* (%)	21 (50.0)	26 (61.9)	0.272
Minimally invasive approach, *n* (%)	34 (81.0)	37 (88.1)	0.365
Age, mean ± SD (years)	66.6 ± 12.6	64.1 ± 10.3	0.326
FEV1, % predicted, mean ± SD	76.3 ± 17.7	78.5 ± 18.6	0.586
DLCO, % predicted, mean ± SD	77.7 ± 16.8	79.9 ± 17.0	0.548
Charlson Comorbidity Index, median (IQR)	5.0 (4.0–6.0)	5.0 (4.0–6.0)	0.678
Days with drain, median (IQR)	2.0 (2.0–2.0)	2.0 (1.0–3.0)	0.953

Statistical tests: chi-square for categorical variables, Student's t test for age, FEV1 and DLCO, and Mann–Whitney U for days with drain and for the Charlson Comorbidity Index. All major resections were performed for primary lung cancer. The Charlson Comorbidity Index is age-adjusted and includes the tumour component, which in this predominantly oncological cohort contributes substantially to the total score. DLCO was available in 80 patients (40 per group); in the 4 remaining patients, all of whom underwent non-anatomical resection for benign disease, preoperative assessment was limited to spirometry. Abbreviations: CTD, conventional tube drainage; DLCO, diffusing capacity of the lung for carbon monoxide; ETD, electronic tube drainage; FEV1, forced expiratory volume in one second; IQR, interquartile range; SD, standard deviation.

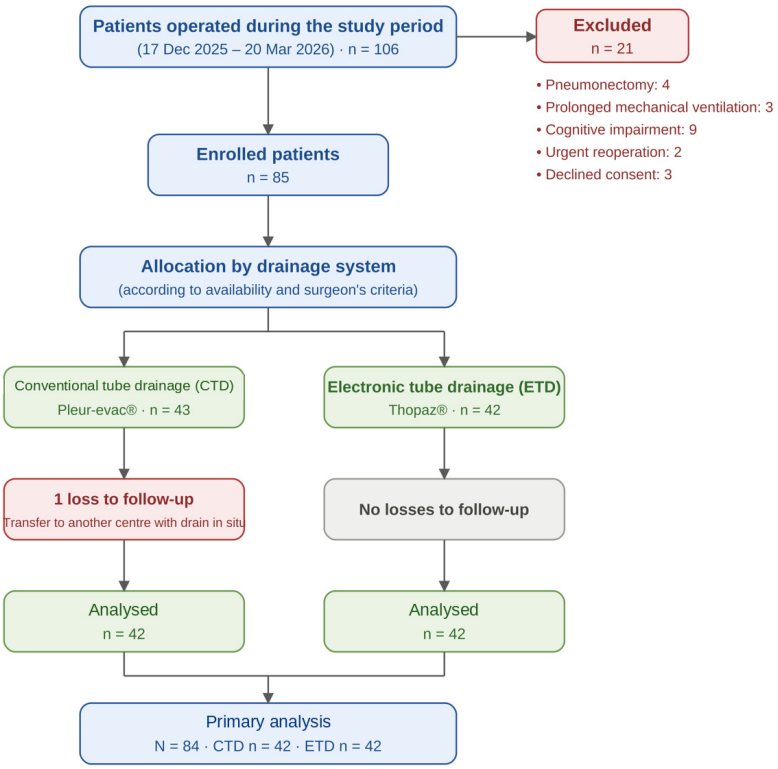


Figure 1. STROBE-style participant flow diagram.

The GEI did not reach statistical significance (Table 2): the mean difference was 0.57 points in favour of ETD (95% CI −0.20 to 1.32; $p = 0.246$; d = 0.31). No subscale was individually significant, although overall satisfaction showed the most pronounced trend (d = 0.41; $p = 0.086$). Figure 2 shows the effect sizes for the GEI and its subscales.

Table 2. Global Experience Index (GEI), autonomy and willingness to reuse (N = 84).

Variable	CTD Mean ± SD/Med (IQR)	ETD Mean ± SD/Med (IQR)	Mean Diff. (95% CI)	*p*	Cohen's d (95% CI)
GEI—scale 0–10; higher score = better experience					
GEI Mean [a]	7.17 ± 1.97/7.75 (6.00–8.75)	7.73 ± 1.69/7.75 (6.75–9.25)	0.57 (−0.20 to 1.32)	0.246	0.31 (−0.12 to 0.74)
Comfort	7.05 ± 2.28/7.50 (6.00–9.00)	7.14 ± 2.44/8.00 (5.00–9.00)	0.10 (−0.94 to 1.10)	0.828	0.04
Functional interference	5.88 ± 2.54/6.00 (5.00–8.00)	6.57 ± 2.64/7.00 (5.00–9.00)	0.69 (−0.43 to 1.79)	0.213	0.27
Perceived safety	8.14 ± 2.21/9.00 (8.00–10.00)	8.79 ± 1.37/9.00 (8.00–10.00)	0.64 (−0.10 to 1.42)	0.187	0.35
Overall satisfaction	7.60 ± 2.32/8.00 (7.00–9.00)	8.43 ± 1.67/9.00 (7.00–10.00)	0.83 (−0.03 to 1.67)	0.086	0.41
Other variables					
Autonomy (1–4)	2.40 ± 0.83/2.00 (2.00–3.00)	2.52 ± 1.04/2.50 (2.00–3.00)	0.12 (−0.29 to 0.49)	0.609	0.13
Would reuse (1–5)	3.76 ± 1.01/4.00 (3.00–4.00)	4.12 ± 0.99/4.00 (3.00–5.00)	0.36 (−0.07 to 0.74)	0.077	0.36

[a] Primary outcome variable. A positive mean difference favours ETD, since a higher score indicates a better experience. *p* values from the Mann–Whitney U test; 95% CI obtained by bootstrap. No correction for multiple comparisons was applied.

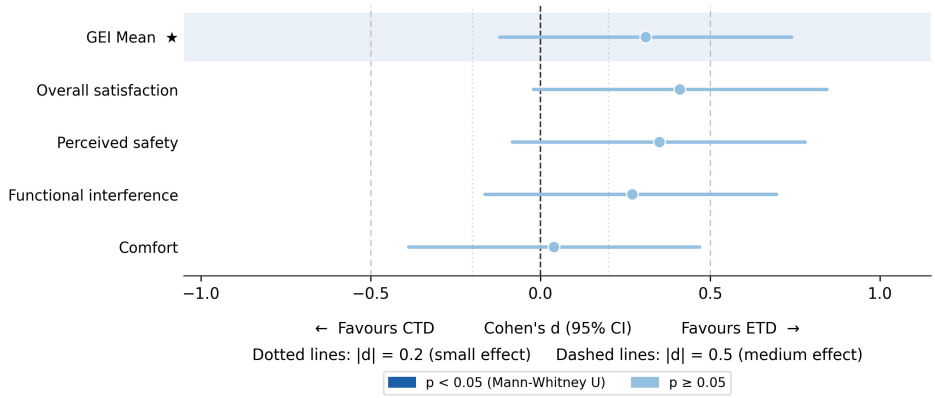


Figure 2. Effect sizes (Cohen's d with 95% CI) for the Global Experience Index (GEI) and its subscales (N = 84). ★ Primary outcome. All effects favour ETD. Positive values indicate a better experience with ETD. CTD: conventional tube drainage; ETD: electronic tube drainage.

The mean sleep-disturbance score (items 1–8) was lower with ETD without reaching statistical significance (difference −0.77; 95% CI −1.57 to 0.05; $p = 0.181$; d = 0.40). The direction of effect favoured ETD for every item. Item 2 (noise from monitors and equipment alarms) was the only significant item (difference −1.31; 95% CI −2.32 to −0.30; $p = 0.032$; d = 0.53). Figure 3 shows the distribution of the mean sleep-disturbance score by group;

item-level results are detailed in Table 3. The mean score was computed for patients with all items available (CTD $n = 37$; ETD $n = 39$).

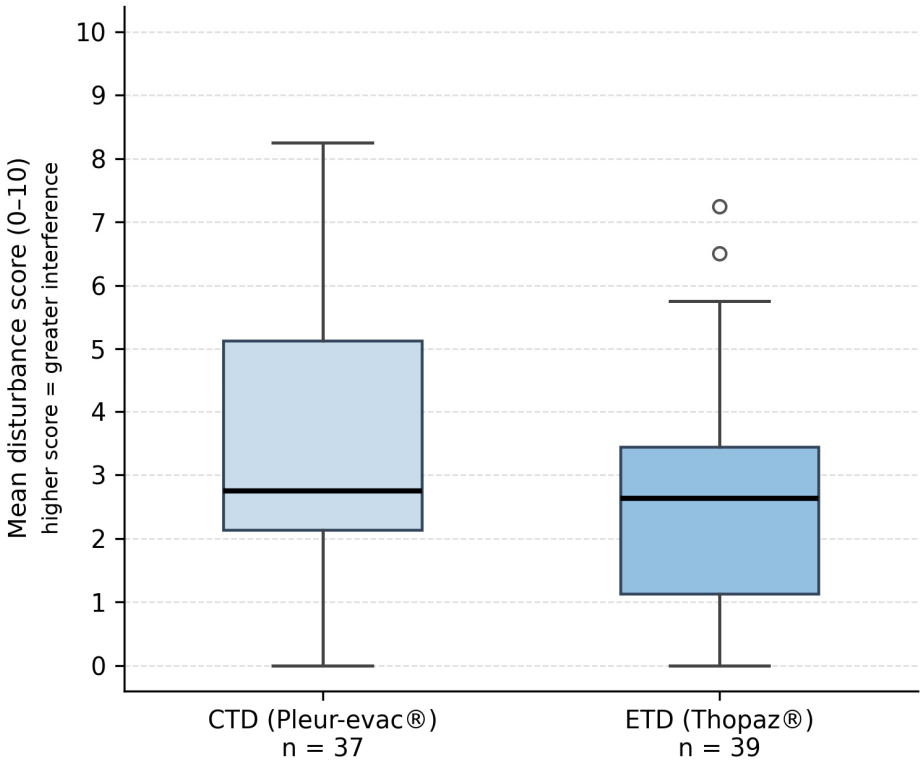


Figure 3. Distribution of the mean sleep-disturbance score (items 1–8 of the Carrera-Hernández et al. questionnaire) by group. Higher scores indicate greater interference with sleep; lower scores are therefore better. Circles denote outliers. $p = 0.181$ (Mann–Whitney U). CTD: conventional tube drainage; ETD: electronic tube drainage.

Table 3. Sleep-disturbing factors questionnaire (adapted from Carrera-Hernández et al. [17]).

Variable	CTD Mean ± SD/Med (IQR)	ETD Mean ± SD/Med (IQR)	Mean Diff. (95% CI)	*p*	Cohen's d (95% CI)
Sleep-disturbing factors—scale 0–10; higher score = greater interference					
Mean score, items 1–8 (CTD N = 37; ETD N = 39)	3.39 ± 2.10/2.75 (2.13–5.13)	2.62 ± 1.72/2.63 (1.13–3.44)	−0.77 (−1.57 to 0.05)	0.181	0.40 (−0.05 to 0.85)
Item 1—Worries/nervousness	4.02 ± 3.09/3.00 (2.00–7.00)	3.29 ± 3.16/2.00 (1.00–5.00)	−0.74 (−2.05 to 0.56)	0.210	0.24
Item 2—Monitor/alarm noise [a]	3.07 ± 2.81/2.00 (0.00–5.00)	1.76 ± 2.09/1.00 (0.00–2.00)	−1.31 (−2.32 to −0.30)	0.032	0.53
Item 3—Staff voices at night	3.07 ± 2.62/2.50 (1.00–5.00)	2.43 ± 2.21/2.00 (1.00–3.00)	−0.64 (−1.61 to 0.35)	0.315	0.27
Item 4—Night-time care interventions	2.52 ± 2.80/2.00 (0.00–4.00)	2.07 ± 2.56/1.00 (0.00–2.00)	−0.45 (−1.48 to 0.67)	0.670	0.17
Item 5—Pain during the night	3.90 ± 3.07/4.00 (1.00–6.00)	3.62 ± 3.26/2.00 (1.00–7.00)	−0.29 (−1.69 to 1.13)	0.662	0.09
Item 6—Discomfort from drains	3.81 ± 2.83/4.00 (1.00–6.00)	3.14 ± 2.71/2.50 (1.00–6.00)	−0.66 (−1.80 to 0.53)	0.293	0.24

Item 7—Ambient light	2.05 ± 2.09/2.00 (0.00–3.00)	2.05 ± 2.62/1.00 (0.00–2.00)	0.00 (−1.04 to 0.96)	0.526	0.00
Item 8—Other patients	3.21 ± 3.22/2.00 (0.00–7.00)	2.24 ± 2.62/1.00 (0.00–4.00)	−0.98 (−2.29 to 0.18)	0.271	0.33

[a] Statistically significant ($p < 0.05$). A higher score indicates greater interference with sleep, so a negative mean difference favours ETD. The mean of items 1–8 was computed only for patients with all items available (CTD $n = 37$; ETD $n = 39$). p values from the Mann–Whitney U test; 95% CI obtained by bootstrap. No correction for multiple comparisons was applied.

The Pompili scale was the only variable reaching statistical significance in the analysis: mean difference 0.31 (95% CI 0.05 to 0.54; $p = 0.026$; d = 0.51). At item level, item 7 (night-time comfort) was significant on both tests ($p = 0.013$; d = 0.57). Figure 4 shows the item-level effect sizes; full results are presented in Table 4.

Table 4. Pompili scale—mobility with the device (N = 84).

Variable	CTD Mean ± SD/Med (IQR)	ETD Mean ± SD/Med (IQR)	Mean Diff. (95% CI)	*p*	Cohen's d (95% CI)
Pompili—scale 1–5; higher score = better mobility					
Pompili Mean [a]	2.73 ± 0.59/2.63 (2.25–3.13)	3.04 ± 0.62/3.13 (2.50–3.50)	0.31 (0.05 to 0.54)	0.026	0.51 (0.07 to 0.94)
P1—Getting out of bed	3.12 ± 1.13/3.00 (2.00–4.00)	3.52 ± 0.97/4.00 (3.00–4.00)	0.40 (−0.06 to 0.85)	0.092	0.38
P2—Walking in room/corridor	3.12 ± 1.35/3.50 (2.00–4.00)	3.64 ± 1.03/4.00 (3.00–4.00)	0.52 (0.02 to 1.01)	0.093	0.44
P3—Personal comfort/other patients	2.90 ± 0.82/3.00 (2.00–3.00)	3.24 ± 0.82/3.00 (3.00–4.00)	0.33 (−0.03 to 0.67)	0.071	0.41
P4—Ease of carrying	3.40 ± 0.99/3.50 (3.00–4.00)	3.57 ± 1.11/4.00 (3.00–4.00)	0.17 (−0.26 to 0.59)	0.293	0.16
P5—Common areas/visits	3.10 ± 0.85/3.00 (3.00–4.00)	3.33 ± 0.93/3.00 (3.00–4.00)	0.24 (−0.14 to 0.60)	0.168	0.27
P6—Comfort at hospital discharge	2.17 ± 0.96/2.00 (1.00–3.00)	2.60 ± 1.13/2.50 (2.00–4.00)	0.43 (−0.02 to 0.89)	0.078	0.41
P7—Night-time comfort [a]	2.14 ± 0.93/2.00 (2.00–3.00)	2.71 ± 1.09/3.00 (2.00–4.00)	0.57 (0.12 to 0.95)	0.013	0.57
P8—Would change device [b,c]	1.88 ± 0.45/2.00 (2.00–2.00)	1.67 ± 0.61/2.00 (1.00–2.00)	−0.21 (−0.44 to 0.02)	0.029	0.40

[a] Statistically significant on both tests ($p < 0.05$). [b] Statistically significant on the Mann–Whitney U test only. [c] Reversed item: a lower score indicates greater satisfaction with the system, so here a negative mean difference favours ETD. The 95% CI for P8 includes zero because of distributional skewness; significance was confirmed by the Mann–Whitney U test ($p = 0.029$). For all other items a higher score indicates better mobility, so a positive mean difference favours ETD. p values from the Mann–Whitney U test; 95% CI obtained by bootstrap. No correction for multiple comparisons was applied.

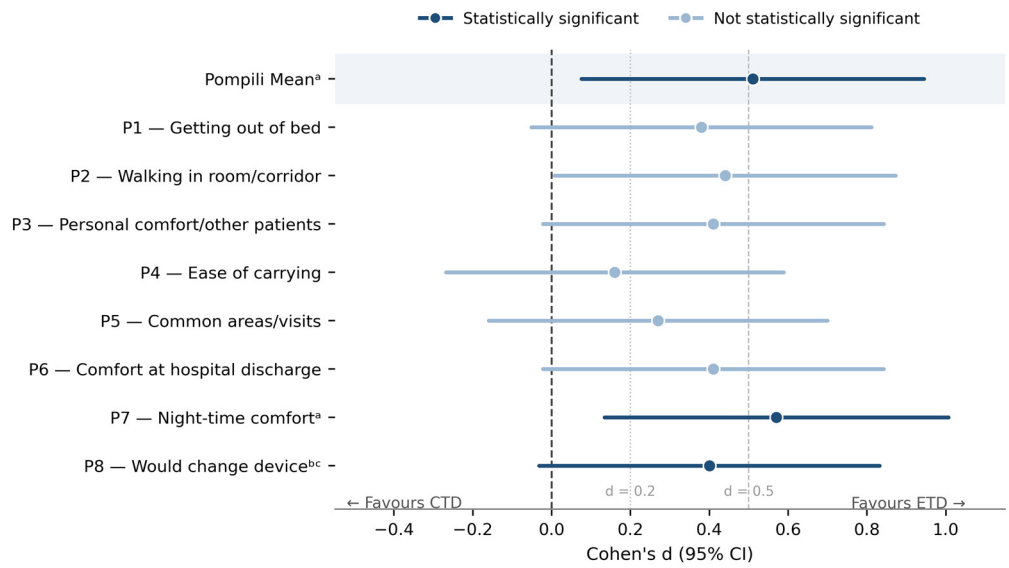


Figure 4. Effect sizes (Cohen's d with 95% CI) for the Pompili scale and its items (N = 84). [a] Statistically significant on both tests ($p < 0.05$). [b] Statistically significant on the Mann–Whitney U test only. [c] Reversed item (P8): a lower raw score indicates greater satisfaction with the system; its sign has been inverted here so that, as for all other items, a positive value favours ETD. Confidence intervals are analytical; discrepancies with the bootstrap intervals reported in Table 4 reflect the difference between the two approaches. Abbreviations: CTD, conventional tube drainage; ETD, electronic tube drainage.

4. Discussion

ETD did not demonstrate a statistically significant superiority over CTD in overall patient experience as measured by the GEI. The pattern of results, however, warrants a more nuanced reading than that of a simply negative finding. All four GEI domains showed effects consistently favouring ETD, as did every secondary outcome analysed. This unidirectional coherence, reproduced across all the instruments used, suggests that ETD generates a globally better subjective experience, even though the differences do not reach statistical significance with the available sample. The results are consistent with previous evidence: both the trial by Pompili et al. [7] and the meta-analysis by Embalabala et al. [8] describe a signal favouring ETD in patient experience that is weak and discordant depending on the instrument and the timing of measurement.

The Pompili scale was the only instrument reaching statistical significance in the analysis, with a moderate effect size. This finding is coherent with the nature of ETD: a compact, portable, and silent device, as opposed to a system that requires a static water chamber and an external stand. The most pronounced differences were observed in night-time comfort when moving or changing position in bed, and in a lower willingness to change device, which reflects a more genuine satisfaction with the system. These results connect with those of Bertolaccini et al. [11], who reported greater patient satisfaction with digital drainage, and with the trial by Pompili et al. [7], which identified advantages of the electronic system in mobility and in readiness for discharge home. The item-level response profile, with effects favouring ETD across every dimension explored (although only two reached significance), suggests that the mobility advantage of ETD is a real and reproducible phenomenon rather than an isolated finding.

Night-time rest showed a pattern of lower interference with ETD that did not reach statistical significance for the mean sleep-disturbance score. Item 2, which specifically addresses noise from monitors and equipment alarms, was the only significant item, with a moderate effect size. This result suggests that the advantage of ETD is concentrated in the

acoustic dimension of the postoperative environment, to which the drainage system is a direct contributor. Noise is a well-documented cause of sleep disruption in hospitalised patients, with electronic and alarm-based sources among the most disruptive [20]. In this context it is relevant to note that the conventional system used in our unit is a dry-seal device, unlike the wet water-seal systems used in most published works. The characteristic bubbling of a wet seal represents an additional source of night-time noise that is absent in our setting, which may be attenuating between-group differences in this domain and makes the significance of item 2 all the more striking.

The presence of two outliers in the electronic group with high disturbance scores widens the dispersion of that group and may be contributing to the dilution of the overall difference between systems (Figure 3). Their existence underscores the heterogeneity of individual responses to the device, a dimension that future studies should explore.

Overall satisfaction on the GEI and willingness to use the same system again in the event of further surgery approached statistical significance without reaching it. Both variables capture the patient's appraisal of the device as a whole, spontaneously integrating comfort, mobility, sleep, and safety. The consistently favourable trend for ETD in these two variables reinforces the general message of this work beyond the statistically significant results. The convergence of three conceptually distinct measures—GEI overall satisfaction, willingness to reuse and the Pompili change-of-device item—all pointing in the same direction adds weight to the argument that patients with ETD have a subjectively better experience with their device. In particular, the agreement between willingness to use the same system again—a prospective, stand-alone question—and item P8 of the Pompili scale, a retrospective judgement measured independently within a structured instrument, should be read as cross-validation between related but distinct constructs rather than as redundancy.

The instruments used—the GEI, the sleep-disturbing factors questionnaire and the Pompili scale—cover complementary and non-overlapping domains: comfort and perceived safety with the device, interference of environmental factors with night-time rest, and the ability to move and function autonomously during admission. Taken together, they draw a coherent picture: ETD is associated with a subjectively better experience across every dimension explored, with differences reaching statistical significance in mobility with the device and in noise-related sleep disturbance, and consistent but non-significant trends in overall satisfaction. The incorporation of PROMs and PREMs into thoracic surgery research responds to a growing demand from regulatory agencies and scientific societies, which recognise patient experience as a clinical outcome of the first order [10]. This under-use is not merely theoretical: in a recent international survey of ESTS and JACS members, 58.5% of thoracic surgeons reported never having collected health-related quality of life data in their practice, while most respondents simultaneously identified such measures as the most relevant patient-reported outcome [21]. Instruments designed specifically for lung surgery are beginning to fill this gap [22], within a broader shift towards patient-centred perioperative care in the specialty [23].

Within enhanced recovery programmes in thoracic surgery, evidence on the comparative experience of drainage systems has direct implications for clinical practice and for device procurement decisions.

These findings are relevant to the perioperative care of the thoracic surgical oncology patient. For a patient operated on for lung cancer, the postoperative course does not end at discharge: definitive staging and, frequently, adjuvant treatment follow, and functional status at discharge conditions tolerance of that pathway. Within enhanced recovery protocols, in which early mobilisation is a central component, a device that interferes less with walking and with night-time rest addresses precisely the domains that matter in this population. Our data do not allow any claim about oncological outcomes, which were not

assessed; what they suggest is that the choice of drainage device has consequences for the postoperative experience of a predominantly oncological cohort.

This study has several limitations. The observational design without formal randomisation entails a potential risk of indication bias. Although the groups proved comparable across all baseline variables analysed, including pulmonary function and comorbidity, baseline comparability does not substitute for randomisation, and residual confounding related to surgeon preference cannot be excluded. Surgical approach, number of ports, and anaesthetic technique were uniform across the unit and therefore could not act as differential confounders between groups. The GEI is an instrument developed ad hoc for this study, in the absence of validated instruments specific to this clinical context [15,16]; its results must therefore be interpreted with the caution demanded by the lack of external validation, and the present study may itself serve as a basis for future formal validation against established measurement-property criteria [24]. The standard deviation observed in the final sample was higher than the interim estimate on which the sample size was recalculated (1.97 in CTD and 1.69 in ETD; pooled SD 1.84). With this value, 53 patients per group would have been required to preserve 80% power, so the achieved power for the predefined 1-point difference was approximately 70%. Moreover, the difference actually observed was 0.57 points, well below the threshold assumed to be clinically relevant; detecting a difference of that magnitude would have required approximately 163 patients per group. The sleep-disturbing factors questionnaire shares this limitation: its own authors acknowledge that it is a self-developed instrument that has not undergone formal validation [17], and two adaptations were introduced in the present study (a 0–10 graphic rating scale and a summary mean of items 1–8 not contemplated in the original instrument). In addition, as no measure of global sleep quality was included, it cannot be affirmed that patients with ETD slept better, only that they reported less interference from specific factors. Comparability with the previous literature is conditioned by the use of a dry-seal conventional system rather than the wet seal employed in most published studies. The single-centre design limits the generalisability of the results, although the volume of the centre supports the representativeness of the sample within the setting of high-volume thoracic surgery. Oncological variables such as stage, histology, and adjuvant treatment were not recorded, so no inference can be drawn regarding oncological outcomes. Finally, given the exploratory nature of the analysis and the absence of correction for multiple comparisons, the results for secondary outcomes should be read as signals that guide future hypotheses, and their statistical significance cannot be regarded as confirmatory in the strict sense.

5. Conclusions

ETD did not demonstrate a statistically significant superiority over CTD in overall patient experience as measured by the GEI. The consistently favourable pattern for ETD across every dimension explored, reaching statistical significance in mobility with the device and in noise-related interference with night-time rest, indicates that the choice of drainage system is not a matter of indifference from the patient's perspective. In a cohort in which more than three quarters of patients were operated on for an oncological indication, these findings are directly relevant to enhanced recovery after surgery (ERAS) programmes in thoracic surgery, in which early mobilisation and night-time rest are explicit care objectives rather than secondary considerations. The accumulated evidence on the objective advantages of ETD [25] is thus complemented by data on the patient's subjective experience pointing in the same direction. These findings suggest that the benefit of electronic drainage lies in specific domains of the postoperative experience, particularly mobility and night-time rest, which are explicit care objectives within enhanced recovery programmes. Confirmation via adequately powered, preferably multicentre, studies would

be required before recommending the systematic incorporation of electronic drainage into postoperative protocols after lung resection.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/cancers18233816/s1, Supplementary Material Table S1: Patient experience questionnaire.

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Abbreviations

The following abbreviations are used in this manuscript:

CTD	Conventional tube drainage
ERAS	Enhanced Recovery After Surgery
ETD	Electronic tube drainage
GEI	Global Experience Index
IQR	Interquartile range
NRS	Numerical rating scale
PREMs	Patient-reported experience measures
PROMs	Patient-reported outcome measures
SD	Standard deviation

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