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ORIGINAL ARTICLE

A retrospective analysis of the duration of mechanical ventilation in Scandinavian paediatric heart centres

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Abstract

Aim: Early extubation after cardiac surgery shortens paediatric intensive care unit (PICU) length of stay (LOS) and decreases complications from mechanical ventilation (MV). We explored the duration of MV in Scandinavian paediatric heart centres.

Methods: We retrospectively reviewed the MV duration and PICU LOS of 696 children operated for atrial septal defect (ASD), ventricular septal defect (VSD), tetralogy of Fallot (TOF) or total cavopulmonary connection (TCPC) in four Scandinavian centres in 2015–2016. Neonates ($n = 90$) were included regardless of heart surgery type.

Results: Patients with ASD were extubated at a median of 3.25 h (interquartile range [IQR] 2.00–4.83), followed by patients with TCPC (median 5.00 h, IQR 2.60–16.83), VSD (median 7.00 h, IQR 3.69–22.25) and TOF (median 18.08 h, IQR 6.00–41.38). Neonates were not extubated early (median 94.42 h, IQR 45.03–138.14). Although MV durations were reflected in PICU LOS, this was not as apparent among those extubated within 12 h. The Swedish centres had shortest MV durations and PICU LOS. Extubation failed in 24/696 (3.4%) of patients.

Conclusion: Scandinavian paediatric heart centres differed in the duration of postoperative MV. Deferring extubation up to 12 h postoperatively did not markedly prolong PICU LOS.

KEYWORDS
Cardiac surgery, congenital cardiovascular malformations, extubation, mechanical ventilation, paediatric intensive care

1 | INTRODUCTION

Children with open-heart surgery are a major patient group in paediatric intensive care. Optimizing postoperative processes for these patients is therefore essential. The duration of mechanical ventilation (MV) is a key determinant of postoperative length of stay (LOS) in paediatric intensive care units (PICUs). In adults, early extubation after cardiac surgery reduces length of stay (LOS) in the intensive care unit (ICU) and leads to lower costs without increased risks for the patient.[1,2] With the development of fast-track protocols, there

Abbreviations: ASD, atrial septal defect; CPB, cardiopulmonary bypass; LOS, length of stay; MV, mechanical ventilation; OR, operating room; PICU, paediatric intensive care unit; TCPC, total cavopulmonary connection; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

has been growing interest in early extubation practices in children undergoing cardiac surgery. In retrospective studies,[3–10] children extubated early were older, had fewer comorbidities and had shorter cardiopulmonary bypass (CPB) times and simpler surgeries.[10,11] The definition of early extubation has varied from extubating in the operating room (OR)[4,5,9,12] up to 6 h postoperatively.[13] Extubation of neonates within 24 h of the operation has also been considered early.[14]

Early extubation is feasible in most children after cardiac surgery under CPB. In these children, early extubation was associated with shorter hospital LOS,[2,5,12] shorter PICU LOS,[2,5,12] decreased incidence of sepsis,[13] earlier start of enteral feeds[15] and lower total costs.[14] However, early extubation has no intrinsic value. Rather, the goal should be identifying the patients for whom early extubation is feasible and safe.

To date, there are no data on extubation practices in children undergoing cardiac surgery in Scandinavian paediatric cardiac centres. The aim of this retrospective, multicentre study was to explore the duration of MV and PICU LOS in children undergoing common types of cardiac surgery with low mortality risk[16] in four Scandinavian paediatric cardiac centres in 2015–2016.

Key Notes

- The duration of mechanical ventilation after paediatric heart surgery may influence patient flow and outcomes in paediatric intensive care.
- In a retrospective setting, we found that four Scandinavian paediatric heart centres had differences in the duration of mechanical ventilation and postoperative paediatric intensive care unit length of stay.
- Evaluation of current extubation practices may serve benchmarking purposes and facilitate protocol development in paediatric cardiac critical care.

2 | METHODS

This retrospective study was performed in the Helsinki University Hospital, Sahlgrenska University Hospital, Skåne University Hospital and Oslo University Hospital. These are the tertiary care hospitals responsible for care of all paediatric cardiac surgery patients requiring open-heart surgery in Finland, Sweden and Norway.

All paediatric patients aged 0–16 years who had open-heart surgery for atrial septal defect (ASD), ventricular septal defect (VSD), tetralogy of Fallot (TOF) or total cavopulmonary connection (TCPC) procedure performed under CPB and without preoperative PICU or perioperative extracorporeal membrane oxygenation (ECMO) treatment between 1 January 2015 and 31 December 2016 were included. Neonates aged <30 days meeting these criteria were included regardless of surgery type and were analysed as a distinct group.

The primary objective was to compare extubation times and the duration of mechanical ventilation after each surgery in the four centres. The secondary objectives were to determine whether there was a connection between extubation time and PICU LOS. We were particularly interested in the early range of MV duration up to 12–24 h postoperatively. In addition, we separately analysed the population extubated from 3 to 12 h postoperatively. By choosing this cohort, we sought to include those extubated early in the PICU and to exclude those extubated in the OR or in the recovery room.

Each centre organised the surgery and the postoperative care according to their own practices. All patients were postoperatively admitted to PICU except in Gothenburg; in this centre, patients with ASD were extubated in the OR and admitted to a paediatric high-dependency unit. Paediatric anaesthesiologists were responsible for postoperative care in the PICU. The patients were extubated when deemed suitable according to the clinical judgement of the responsible anaesthesiologist. Patients were discharged to the ward when judged appropriate. The minimum requirement was achievement of stable vital functions without support. Extubation failure was defined as any unplanned reintubation during PICU admission.

2.1 | Ethical aspects

The study was approved by the Ethics Committee of Helsinki University Hospital (HUS/3636/2017 §295) and the Research Committee of the Helsinki University Hospital (HUS/185/2018 §6).

2.2 | Data collection

Perioperative data were collected by a single researcher in each centre from the centre's patient record system. Diagnoses and exclusion criteria were manually checked individually in each centre by the single researcher in that centre.

2.3 | Statistical analyses

Data are presented as numbers and percentages for categorical data or median and interquartile range (IQR) for continuous data. The Kruskal-Wallis test was used to compare continuous data between the centres. Spearman's correlation was used to assess the associations. A p-value <0.05 was considered statistically significant. All analyses were performed using R version 4.0.4 (R Foundation for Statistical Computing, Vienna, Austria). Plots were generated using the ggplot2 package.[17]

3 | RESULTS

Altogether, 696 children with open-heart surgery were included from the four participating paediatric heart centres. Of these,

TABLE 1 Repartition of patients between centres and by procedure

	VSD	TOF	ASD	TCPC	Neonates	All
Gothenburg	48	37	47	23	52	207
Lund	85	47	31	18	25	206
Helsinki	69	26	36	24	13	168
Oslo	57	30	13	15	0	115
All	259	140	127	80	90	696

Note: Data are presented as number of patients.

Abbreviations: ASD, atrial septal defect; TCPC, total cavopulmonary connection; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

90/696 were neonates and 606/696 were older children. The most common procedures were VSD (259/696), followed by TOF correction (140/696), ASD seclusion (127/696) and TCPC construction (80/696) (Table 1). A scatter plot with the MV duration and length of stay of all patients is shown in Figure 1A.

The length of postoperative invasive mechanical ventilation and PICU LOS varied by procedure (Tables 2 and 3, respectively) and between centres (Figure 2). In Oslo, neonates were discharged to neonatal intensive care unit instead of the paediatric ward and were not included in the study. There was a significant ($p < 0.001$) correlation between the duration of MV and PICU LOS for all diagnoses. This correlation was clear for long MV durations but was very modest in the large group of patients extubated within 3–12 h of open-heart surgery (Figure 1A,B, Table S1). Excluding neonates from the analyses did not change the results, even if inclusion of neonates in three of the centres and exclusion in one centre were a major determinant in the differences between centres.

Extubations in the OR occurred mainly in Gothenburg, where 13 patients with ASD, five patients with VSD and seven patients with TCPC were extubated in the OR. In addition, one patient with VSD was extubated in the OR in Oslo. Neonates were not extubated in the OR.

Delayed sternum closure, which influences extubation times, was most common in neonates. Of these, 37/90 (44%) neonates were left with open sternum after the procedure (nine in Helsinki, five in Lund and 23 in Gothenburg). In addition, three patients with VSD in Helsinki and three with TOF (two in Helsinki, one in Gothenburg) had delayed sternum closure.

The overall extubation failure rate was 24/696 (3.4%). All patients with ASD were successfully extubated. Eight patients with VSD, six patients with TOF, four patients with TCPC and six neonates were reintubated. The extubation failure rate for neonates was thus 6/90 (6.7%). The overall extubation failure rate was 3/206 (1.5%) in Lund, 8/207 (3.9%) in Gothenburg, 7/168 (4.2%) in Helsinki and 6/115 (5.2%) in Oslo.

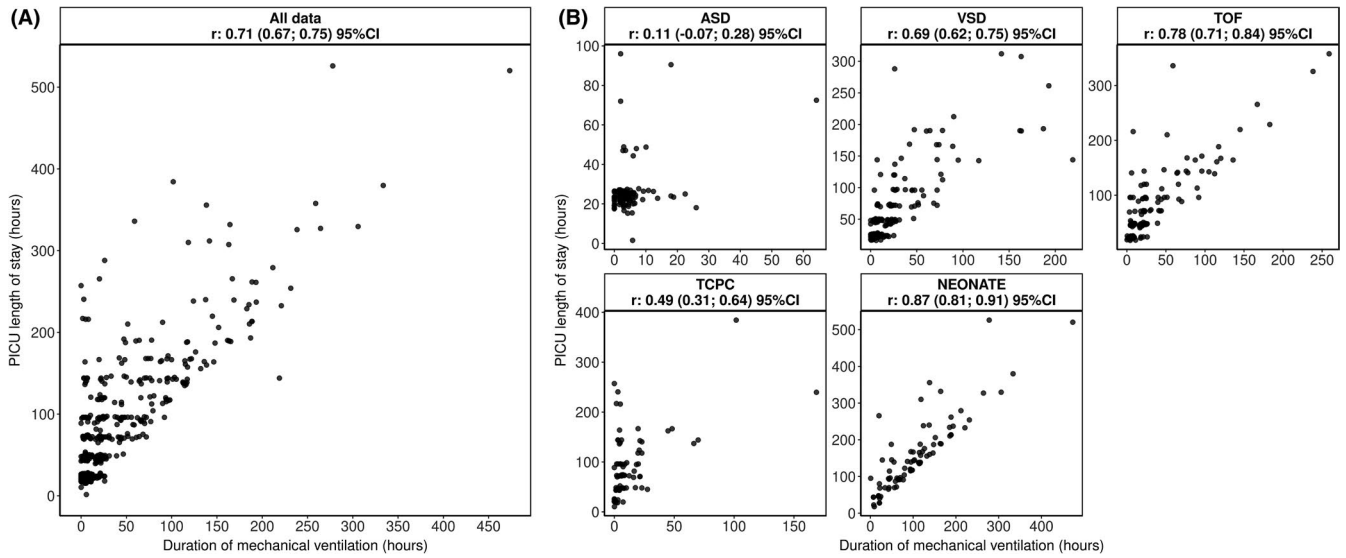

FIGURE 1 (A) Correlation of PICU LOS with the duration of mechanical ventilation. All centres and procedures combined. Grey points represent patients extubated within 12 h. Black points represent those extubated later. LOS, length of stay; PICU, paediatric intensive care unit. (B) Correlation of PICU LOS with the duration of mechanical ventilation. Grey points represent patients extubated within 12 h. Black points represent those extubated later. ASD, atrial septal defect; TCPC, total cavopulmonary connection; TOF, tetralogy of Fallot; VSD, ventricular septal defect

4 | DISCUSSION

This retrospective study in four Scandinavian paediatric heart centres revealed that differences exist in the duration of postoperative MV, especially for more complex surgeries. Despite lack of formal extubation criteria, the duration of MV was less divergent for simpler surgeries, such as ASD or VSD repair. These differences were reflected in PICU LOS, as centres favouring earlier extubation also discharged from PICU earlier. However, LOS did not differ markedly in patients extubated within 12 h of the operation, which suggests that some clinical discretion in the timing of extubation is probably tolerable.

In studies and in practice, early extubation is often combined with other elements of fast-track protocols, which makes it difficult to evaluate the role of extubation practices only.[18] To facilitate patient selection for early extubation, it is necessary to compare current MV duration and other extubation practices within paediatric heart centres. Only then does it become possible to proceed to the comparison of results between centres, and, ultimately, to multicentre trials to validate early extubation practices.

The Scandinavian centres in our study performed well in terms of safety, as the overall extubation failure rate (3.4%) was in the lower range of previously published studies.[4,8,10,12,19] None of the centres in our study had explicit extubation criteria. Indeed, there is no evidence on which to assess extubation readiness in PICUs.[20] Even if increasingly performed elsewhere,[5,19,21,22] neonatal early extubation, let alone neonatal OR extubation, was not performed in Scandinavian centres. This may partly explain the low extubation failure rate we observed, as neonates have a higher risk for failed extubation after cardiac surgery.[4,19,22] The rate of neonatal extubation failure was lower in the centres in this study than in centres that extubate neonates early (7.1% vs 11%).[22] However, the differences in extubation failure rates between our centres were not explained by neonates. Interestingly, as reported by Gaies et al.,[8] the extubation failure rates in our study were lowest in centres with shortest MV durations.

TABLE 2 Length of postoperative invasive mechanical ventilation in hours

	VSD	TOF	ASD	TCPC	Neonates	*p* (centre)[a]
All	7.00 (3.69–22.25)	18.08 (6.00–41.38)	3.25 (2.00–4.83)	5.00 (2.60–16.83)	94.42 (45.03–138.14)	
Gothenburg	5.04(1.22–24.92)	16.50 (6.25–70.17)	2.00 (0.00–2.92)	1.75 (0.00–5.46)	102.12 (61.88–163.65)	<0.001
Lund	6.50 (4.17–16.92)	6.17 (4.67–17.92)	4.83(4.04–6.71)	3.88 (2.56–6.06)	44.58 (20.25–95.08)	<0.001
Helsinki	10.22 (5.17–26.43)	25.11 (18.33–71.40)	3.33 (2.55–4.80)	14.24 (8.05–20.21)	114.58 (80.33–121.83)	<0.001
Oslo	7.00 (3.00–24.00)	22.50 (18.00–46.25)	3.00 (2.00–4.00)	5.00 (3.00–8.50)	–	<0.001
p (procedure)[a]	0.02	<0.001	<0.001	<0.001	0.001	

Note: Data are presented as median (interquartile range).

Abbreviations: ASD, atrial septal defect; TCPC, total cavopulmonary connection; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

[a]*p*-Values refer to the Kruskal-Wallis test between all the treatments in the centre and between centres for the procedure.

TABLE 3 Length of postoperative PICU treatment in days

	VSD	TOF	ASD	TCPC	Neonates	*p* (centre)[a]
All	1.08 (1.00–2.11)	2.01 (1.06–4.00)	1.00 (0.93–1.07)	3.04 (1.88–5.28)	5.74 (3.81–7.89)	
Gothenburg	1.08 (0.96–3.05)	1.94 (1.04–4.71)	0.98 (0.87–1.10)	1.86 (0.89–7.41)	5.74 (3.86–8.54)	<0.001
Lund	1.04 (0.94–1.94)	1.77 (0.92–2.04)	0.95 (0.92–1.00)	2.54 (1.86–4.86)	5.75 (2.85–7.81)	<0.001
Helsinki	2.01 (1.06–2.94)	2.99 (2.02–6.06)	1.03 (0.96–1.07)	3.07 (2.95–4.30)	6.94 (5.87–9.93)	<0.001
Oslo	2.00 (1.00–3.00)	4.00 (2.00–5.00)	1.00 (1.00–1.00)	4.00 (3.00–6.00)	–	<0.001
p (procedure)[a]	<0.001	<0.001	0.04	0.12	0.03	

Note: Data are presented as median (interquartile range)

Abbreviations: ASD, atrial septal defect; TCPC, total cavopulmonary connection; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

[a]*p*-Values refer to the Kruskal-Wallis test between all the treatments in the centre and between centres for the procedure.

Overall, Helsinki had the longest MV durations, followed by Oslo; the two Swedish centres extubated earlier. Patients with ASD were immediately extubated in Gothenburg. Lund and Gothenburg had the shortest MV duration for complex surgeries. This was reflected in the shorter PICU LOS in the Swedish centres. These differences were clinically relevant, as median MV times and PICU LOS were even several times longer in Helsinki or Oslo than in the Swedish centres. These results are consistent with previous studies that have shown that longer MV after paediatric cardiac surgery correlated with longer PICU LOS.[12,13,23] However, virtually all patients with ASD were discharged from the PICU on the first postoperative day in all Scandinavian centres despite differing MV times. Furthermore, the LOS (Table 3) for all diagnoses in the Scandinavian centres was close to those recently[10] reported from a centre performing immediate (OR) extubation.

The organisation of preoperative and postoperative follow-up explains part of the differences between the Scandinavian centres. For instance, patients with ASD are preferably extubated in the OR in Gothenburg, as their postoperative treatment is organised in a high-dependency unit without possibility for invasive mechanical ventilation. This may have also contributed to extubation practices and the duration of MV in other patient groups in Gothenburg; Gothenburg

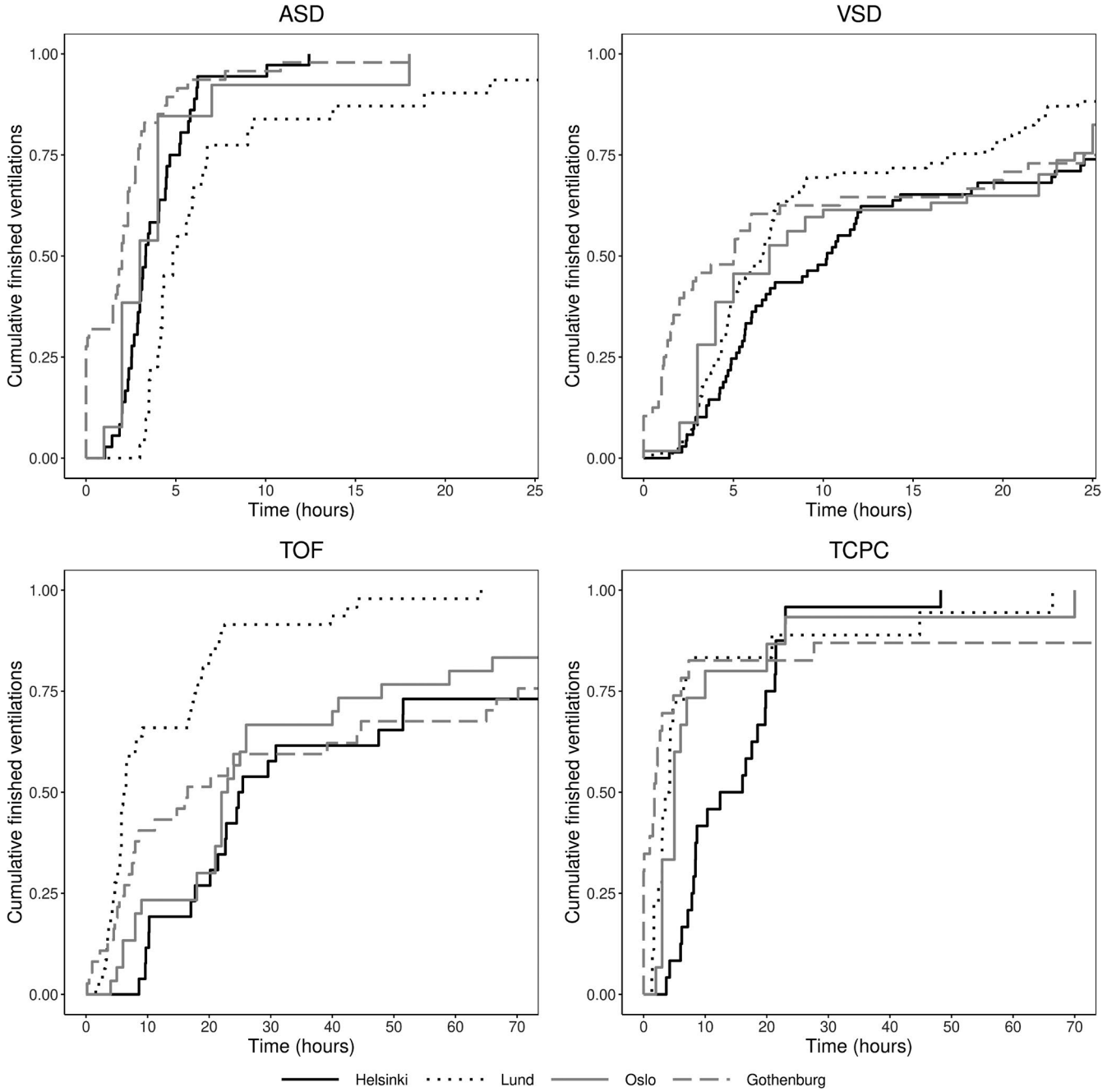

FIGURE 2 Survival plots on the duration of mechanical ventilation (proportion extubated by time in hours) by surgery type and centre. ASD, atrial septal defect; TCPC, total cavopulmonary connection; TOF, tetralogy of Fallot; VSD, ventricular septal defect

had shorter MV times for most conditions. Additionally, whereas alprostadil treatment was used outside of the PICU in Gothenburg, it could only be administered in PICU in the three other centres. Thus, fewer neonates were excluded in Gothenburg because of a preoperative PICU stay.

Traditionally, early extubation and OR extubation after paediatric cardiac surgery have not been recommended due to concerns on achieving haemodynamic stability and controlling bleeding[24] and challenges related to patient flows in the OR. However, Tirotta et al.[10] showed that immediate extubation prolonged OR times only by a few minutes. As failed extubations were associated with mortality,[25] incorrect patient selection for early extubation may also cause harm. If earlier extubation is not always better, it remains unknown how long it is possible to delay extubation without prolonging PICU treatment and risking other related undesirable outcomes, such as increased infection rates,[13] delayed enteral feeds[15] and higher costs.[11,14]

We observed that when extubation was performed within 12 h of operation, the differences in MV duration did not translate to marked differences in PICU length of stay. This suggests that some clinical discretion for extubation time may be possible. According to our results, the clinician may have some liberty to determine the best moment to extubate. It would seem reasonable to wait for optimal staffing, knowing that if the extubation is prolonged to 12 h postoperatively, this could be reflected in a longer PICU LOS.

The main strength of our study was that all centres performing paediatric open-heart surgery within three Scandinavian countries were included, and that data were rigorously collected by a single paediatric anaesthetist in each centre. This added to the comprehensiveness and reliability of the results. The study was limited by its retrospective nature and by the fact that the patient numbers did not allow for the analysis of all relevant outcomes of early extubation. Including characteristics of comorbidities and disease severity may have been relevant, but this was counterbalanced by the fact that all paediatric heart centres within these countries were included, making major differences in case mix unlikely. Furthermore, the group of neonates was not representative of neonates treated in each centre, as varying proportions of neonates from each centre were excluded because of institutional differences in preoperative ICU treatment.

5 | CONCLUSIONS

There were differences in MV duration in Scandinavian paediatric heart centres. Extubation in the OR was uncommon, and neonatal early extubation was not a Scandinavian practice. Under these circumstances, deferring extubation by some hours up to 12 h postoperatively, as judged appropriate by the attending physician, was not markedly reflected in a longer PICU LOS.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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