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# On-Table Extubation (OTE) in Cardiac Surgery in a New, Resource-Limited Center in a Small Island Nation: A Retrospective Study

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## Abstract

### Background

On-table extubation (OTE) represents the most accelerated form of fast-track cardiac anaesthesia and enhanced recovery after surgery. Evidence from resource-limited cardiac surgical centres remains scarce. This study evaluates the feasibility, safety, and early postoperative outcomes of OTE in a newly established cardiac surgical programme.

### Methods

A retrospective observational study was conducted including 202 consecutive patients undergoing cardiac surgery between January 2020 and December 2023. All patients were managed using a standardized perioperative protocol incorporating short-acting anaesthetic agents, bispectral index (BIS)-guided anaesthesia, and bilateral erector spinae plane block (ESPB). Primary outcomes included ICU length of stay, hospital length of stay, and reintubation rate.

### Results

Among 202 patients, 61 (31.2%) underwent successful OTE. The cohort had a mean age of 49.3 ± 19.4 years, with male predominance (60.6%). Valve surgery was the most common procedure group, followed by CABG and congenital repairs. Mean ICU stay in the OTE group was 3.65 days. Reintubation occurred in 4 patients (6.5%), primarily due to respiratory acidosis. No mortality was observed in our cohort.

### Conclusions

OTE is feasible and apparently safe in selected cardiac surgical patients in a newly established, resource-limited environment when supported by structured anaesthetic and perioperative protocols. However, it should remain a selective, physiology-guided strategy rather than a universal extubation endpoint. Gradual adoption of OTE has the potential to enhance ICU productibility, reduce reliance on prolonged mechanical ventilation, and support the sustainability of local cardiac surgical services.

**Keywords:** On-table extubation; cardiac surgery; fast-track anaesthesia; enhanced recovery; erector spinae plane block.

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## Introduction

The evolution of perioperative care in cardiac surgery represents one of the most important advances in contemporary cardiothoracic practice. Historically, postoperative management routinely involved prolonged mechanical ventilation, often extending into the first postoperative night or beyond. This approach was largely driven by the use of high dose opioid-based anaesthesia, limited intraoperative monitoring capabilities, and concerns regarding postoperative haemodynamic instability and myocardial ischaemia [1].

Over the past three decades, substantial progress in anaesthetic pharmacology, surgical techniques, and cardiopulmonary bypass (CPB) management has enabled the development of "fast track" cardiac anaesthesia protocols. These protocols aim to safely shorten the duration of mechanical ventilation, reduce intensive care unit (ICU) and hospital length of stay, and optimise resource utilisation without compromising patient safety. Fast track extubation (FTE), commonly defined by The Society of Thoracic Surgeons as extubation within 6 hours of arrival in the ICU after cardiac surgery, has become widely adopted in many high volume centres. Multiple studies have demonstrated that early extubation is associated with reduced ICU stay, lower costs, and comparable morbidity and mortality when applied to appropriately selected patients.

On-table extubation (OTE) represents the most accelerated form of fast track recovery, in which the endotracheal tube is removed in the operating theatre immediately after surgery once physiological criteria are met. OTE has been reported in a variety of settings, including coronary artery bypass grafting (CABG), valve surgery, congenital heart surgery, and minimally invasive or transcatheter procedures. Emerging evidence suggests that, in selected patients, OTE may further reduce mechanical ventilation time, facilitate earlier ICU discharge, and improve patient satisfaction without increasing adverse events. However, concerns remain regarding potential risks such as reintubation, respiratory failure, haemodynamic instability, and unrecognised neurological impairment.

Most published data on OTE originate from high volume centres with mature perioperative pathways and robust ICU capacity [2-4]. In contrast, its application in low volume or resource limited cardiac surgical programmes is not well described. In such environments, prolonged postoperative ventilation and extended ICU occupancy pose significant logistical and economic challenges. Strategies that safely reduce ICU dependence, shorten ventilation time, and accelerate recovery therefore have high clinical and system-level relevance.

Regional anaesthesia techniques, particularly paravertebral and fascial plane blocks, have recently emerged as important adjuncts to fast track cardiac pathways. The erector spinae plane block (ESPB) has gained attention as a relatively simple, ultrasound guided technique that provides effective thoracic analgesia with a favourable safety profile. Studies in cardiac surgery have shown that ESPB within enhanced recovery pathways can reduce perioperative opioid consumption, improve pain scores, and support earlier mobilisation and extubation. Incorporating ESPB into multimodal analgesia may therefore be particularly advantageous in programmes seeking to implement OTE.

Against this background, the Maldives has recently established a cardiac surgical service. Within this evolving programme, ICU capacity, ventilator availability, and workforce constraints necessitate efficient perioperative strategies. The present study evaluates the feasibility, safety, and early outcomes of OTE in a newly established cardiac surgical centre in the Maldives. Specifically, we aim to describe the proportion of patients achieving OTE, explore procedure specific feasibility, and assess early outcomes including ICU length of stay, hospital length of stay, haemodynamic stability, and reintubation rates.

## Methods

### Study Design

This retrospective observational study was conducted at a newly established tertiary cardiac surgical centre in the Maldives, serving as the principal national referral hub for adult and paediatric cardiac surgery. The programme operates within a resource-limited context, with constrained ICU bed capacity and limited availability of mechanical ventilators. The requirement for individual informed consent was waived owing to the retrospective analysis of routinely collected data.

### Study Population

All consecutive patients who underwent cardiac surgical procedures between January 2020 and December 2023 were included in this study. This study comprised a heterogeneous mix of adult and paediatric patients undergoing a broad range of cardiac procedures, reflecting the case-mix of a developing cardiac surgical programme.

### Regional Anaesthesia Technique

To support a multimodal, opioid-sparing approach, all patients received a bilateral erector spinae plane block (ESPB) at the T4 level under ultrasound guidance. The probe was positioned longitudinally over the vertebral spine and subsequently moved laterally until the transverse process visualized. The Tuohy needle was then inserted from the cephalic side of the probe until it reached the transverse process. Following negative aspiration and hydro-dissection with normal saline, catheter inserted and fixed at T4 level under ultrasound guidance. A catheter was inserted into the fascial plane deep to the erector spinae muscle, and 20 mL of 0.25% bupivacaine was administered every 4 hours intraoperatively and postoperatively.

### Anaesthetic and Intraoperative Management

All patients were managed using a standardised institutional anaesthetic protocol designed to facilitate early extubation where appropriate. Monitoring included continuous electrocardiography, invasive arterial blood pressure, central venous pressure, capnography, temperature monitoring, and bispectral index (BIS), targeting a BIS value between 40 and 60 to ensure adequate depth of anaesthesia while enabling prompt postoperative neurological recovery.

Anaesthesia was induced with Propofol 2 mg/kg, Fentanyl 2 µg/kg, and Vecuronium 0.08–0.1 mg/kg. Maintenance was achieved using a propofol infusion at 50–100 µg/kg/min combined with sevoflurane at a minimum alveolar concentration (MAC) of approximately 0.8. Standard intraoperative monitoring was supplemented by transoesophageal echocardiography (TEE) using a Philips CX50® system (Koninklijke Philips N.V., USA) in all CPB cases to assess ventricular function, valve competence, and surgical repairs before and after correction.

### Criteria for OTE

OTE was performed only when predefined physiological criteria were met at the conclusion of surgery and after reversal of neuromuscular blockade, in line with published recommendations [4,9]. These criteria included.

*Stable haemodynamics with minimal or no inotropic support

*Normothermia (core temperature >36°C)

Adequate spontaneous ventilation (tidal volume >5 mL/kg)

*Satisfactory oxygenation with fraction of inspired oxygen ($FiO_2$) ≤0.5

*Complete reversal of neuromuscular blockade confirmed clinically

*Patients awake or easily arousable and able to obey simple commands

*Secure surgical haemostasis and absence of excessive chest drainage

Patients who did not meet these criteria were transferred intubated to the ICU for standard postoperative management and ventilatory weaning according to unit protocols, which typically included graded reduction of sedation, spontaneous breathing trials, and extubation when predefined respiratory and haemodynamic parameters were satisfied.

ICU length of stay (LOS), Reintubation within 48 hours of surgery and Total hospital length of stay were the primary outcomes of interest.

Secondary outcomes included qualitative assessment of haemodynamic stability, early postoperative complications (respiratory, cardiovascular, neurological, bleeding-related), and procedure-specific feasibility of OTE. Owing to the observational design and limited sample size, predictors of successful OTE were described descriptively rather than analysed with formal multivariable modelling.

## Results

A total of 202 patients were included in the analysis. The mean age was 49.3 ± 19.4 years, and 60.6% of patients were male. The distribution of surgical procedures included 68 valve surgeries (33.7%), 47 CABG procedures (23.3%), 41 congenital heart defect repairs (20.3%; atrial septal defect [ASD], ventricular septal defect [VSD], or patent ductus arteriosus [PDA]), 34 combined procedures (16.8%), and 12 other complex interventions such as transcatheter aortic valve implantation (TAVI), atrial myxoma excision, and aortic surgery (5.9%). The baseline demographic and preoperative characteristics are summarised in Table 1.

**Table 1. Baseline demographic and preoperative characteristics (n = 202)**

| Variable | Value |
|---|---|
| Age (years), mean ± SD | 49.3 ± 19.4 |
| Male sex | 122 (60.6%) |
| Female sex | 80 (39.4%) |
| Study period | 2020–2023 |
| CABG | 47 (23.3%) |
| Valve surgery | 68 (33.7%) |
| Congenital (ASD/VSD/PDA) | 41 (20.3%) |
| Combined procedures | 34 (16.8%) |
| Others (TAVI, myxoma, aorta) | 12 (5.9%) |
| Mean CPB time (min) | 119.6 ± 63.3 minutes |
| Mean cross-clamp time (min) | 84.5 ± 50.3 minutes |
| High risk cases (Euroscore >6) | 4 patients |

Mean CPB time for the overall cohort was 119.6 ± 63.3 minutes and mean aortic cross-clamp time was 84.5 ± 50.3 minutes. Only four patients were classified as high-risk based on a EuroSCORE greater than 6, reflecting cautious early case selection in the programme's initial years. This heterogeneity in age, pathology, and procedural complexity illustrates the broad surgical spectrum managed in this new center. Of the 202 patients included in the study, 61 patients (31.2%) underwent successful OTE, while 141 patients (68.8%) were extubated later in the ICU following standard weaning protocols (Table 2).

**Table 2. Operative and postoperative extubation-related outcomes**

| Outcome | Value |
|---|---|
| On-table extubation | 61 (31.2%) |
| ICU extubation | 141 (68.8%) |
| Mean ICU stay (OTE group) | 3.65 days |
| Reintubation (OTE group) | 4 (6.5%) |
| Mortality attributable to OTE | 0 |
| Reintubation due to respiratory acidosis (OTE group) | 2 (3.3%) |
| Delayed reintubation (OTE group) | 2 (3.3%) |

In the OTE group, the mean ICU stay was 3.65 days. Reintubation occurred in 4 patients (6.5%), all within the first 24-48 hours postoperatively. There were no deaths directly attributable to OTE.

The reintubation events were attributed to respiratory acidosis in two patients and delayed neurological recovery with inadequate airway protection in two patients. None of the reintubations were associated with surgical complications such as tamponade or significant bleeding, nor with overt haemodynamic instability.

## Procedure Specific Feasibility

Table 3 shows OTE success varied according to procedure type. The highest feasibility was observed in isolated valve surgery and congenital defect closures (ASD/VSD/PDA), followed by selected

**Table 3. Procedure-wise OTE feasibility (qualitative summary)**

| Procedure type | OTE success tendency |
|---|---|
| Isolated valve surgery | High |
| ASD/VSD/PDA repair | High |
| Isolated CABG | Moderate |
| Combined CABG + valve | Not attempted |
| Complex redo surgery | Not attempted |

isolated CABG procedures

## Descriptive Predictors of Successful OTE

Although formal statistical modelling was not performed owing to sample size limitations, descriptive analysis suggests in the table 4 that several factors were associated with a higher likelihood of successful OTE.

**Table 4. Descriptive predictors of successful on table extubation**

| Factor | Association with OTE |
|---|---|
| Short CPB time | Positive |
| Low inotrope requirement | Strong positive |
| Normal LV function | Positive |
| Complex combined surgery | Negative |
| Prolonged cross-clamp time | Negative |
| Adequate ESP block analgesia | Positive |

## Discussion

This study demonstrates that on-table extubation is feasible and appears safe in a resource-limited cardiac surgical environment when embedded within a structured perioperative pathway. An OTE rate of 31.2% was achieved in a heterogeneous case mix that included adult and paediatric patients, isolated and combined procedures, and both coronary and valvular pathologies. The reintubation rate of 6.5% in the OTE group falls within the acceptable range reported in the fast track cardiac anaesthesia literature, where reintubation rates of 2–10% are commonly described for early extubation strategies [3,7,8]. Importantly, there was no mortality directly attributable to OTE, and the causes of reintubation were limited to respiratory acidosis
and delayed neurological recovery without clear surgical or haemodynamic precipitating factors.

These findings add to the growing body of evidence that, in selected patients, OTE can be implemented safely and may contribute to more efficient ICU utilisation. They are particularly noteworthy given the context of a newly established programme in a small, resource limited setting.

Several large-scale and single-centre studies have evaluated early extubation and OTE after cardiac surgery. Badhwar et al. reported that extubation in the operating room after adult cardiac surgery was associated with improved outcomes and reduced costs compared with standard postoperative ventilation [3]. Chamchad et al. similarly observed that immediate extubation in the operating theatre after cardiac surgery led to shorter ICU and hospital stays without an increase in complications [11]. Within enhanced recovery after cardiac surgery protocols, implementation of structured pathways including on-table or very early extubation has been associated with reduced perioperative opioid use, improved patient satisfaction, and shorter hospital stays .

At the same time, not all studies have shown unequivocal benefit. Montes et al. found no clear advantage of tracheal extubation in the operating room after CABG in terms of postoperative morbidity, highlighting that patient selection and institutional experience are critical determinants of success . Early work by Silbert et al. demonstrated that early extubation is feasible and safe in carefully selected patients, but emphasised that it should not be applied indiscriminately [10]. Our observed reintubation rate and absence of OTE-related mortality align with the safety profile reported in these studies and in more recent analyses.

Within the specific domain of OTE, *Malvindi et al.* outlined practical recommendations for increasing adoption, emphasising multidisciplinary protocols, rigorous selection criteria, and clear communication between surgical, anaesthesia, and ICU teams [4]. Our institutional approach standardised anaesthetic technique, structured physiological extubation criteria, and routine TEE assessment is consistent with many of these recommendations. Case reports and small series, including off pump CABG experiences, have further illustrated that OTE can be extended to more complex cohorts as expertise grows.

The shift from traditional high dose opioid anaesthesia towards balanced techniques using short acting agents such as propofol and low dose fentanyl has been fundamental to the development of fast track and OTE strategies. In our cohort, induction with propofol and fentany [l], maintenance with propofol infusion and low MAC sevoflurane, and avoidance of long acting muscle relaxants facilitated rapid emergence and early neurological assessment. BIS guided anaesthesia allowed titration of hypnotic depth to maintain adequate anaesthesia while reducing the risk of delayed awakening. This balanced technique was chosen to avoid excessive opioid dosing and prolonged neuromuscular blockade, both of which are known to delay emergence and extubation.

These elements mirror recommendations from fast track anaesthesia guidelines and trials, which stress the importance of short acting agents, depth of anaesthesia monitoring, and early reversal of neuromuscular blockade to enable safe early extubation [3,7,8,9]. Our experience supports the feasibility of applying these principles even in a low volume, resource limited setting.

Role of regional anaesthesia and multimodal analgesia

Effective analgesia is essential for early extubation, as uncontrolled pain can impair respiratory mechanics, increase sympathetic activation, and impede mobilisation. ESPB has emerged as a promising technique for cardiac surgery, offering extensive thoracic analgesia with a low risk of neuraxial complications. Randomised and observational studies within enhanced recovery frameworks have demonstrated that regional techniques and multimodal analgesia reduce perioperative opioid use and support earlier mobilisation and discharge [4,6,8].

In our study, ESPB was systematically incorporated into the anaesthetic protocol, with continuous bupivacaine administration via catheters. Although we did not quantify opiod consumption or pain scores, qualitative observations suggest that adequate ESPB analgesia contributed to patient comfort, stable respiratory parameters, and the ability to wean from mechanical ventilation promptly.

The descriptive association between effective ESPB and successful OTE in Table 4 is consistent with published evidence that regional techniques are key components of fast track pathways and enhanced recovery after cardiac surgery protocols [4,6,8,10].

Patients with shorter CPB times, lower inotrope requirements, preserved left ventricular (LV) function, effective analgesia from ESPB, and less complex surgical procedures were more likely to be extubated on Table [3,4,6,9,10,14]. Conversely, prolonged cross clamp times, complex combined operations, and impaired ventricular function appeared to reduce the feasibility of OTE. These observations are in line with previously reported predictors in OTE and fast track cohorts.

ESPB was employed with the intention of providing effective anterior thoracic analgesia, reducing systemic opioid requirements, improving respiratory mechanics, and facilitating early mobilisation and extubation. Studies within enhanced recovery after cardiac surgery frameworks have shown that multimodal analgesia including regional techniques can reduce perioperative opioid use and support earlier extubation and discharge.

A key conceptual observation from this study is the distinction between time based fast track protocols and physiology driven OTE. Traditional fast track extubation is commonly defined by a time interval (for example, extubation within 6 hours post ICU admission), which may inadvertently prioritise temporal targets over individual patient physiology [3,7,9,12,13]. In contrast, our OTE approach was explicitly guided by a set of physiological criteria, including haemodynamic stability, adequate spontaneous ventilation, satisfactory oxygenation, normothermia, and neurological recovery.

This physiology driven strategy recognises that readiness for extubation is best assessed by dynamic clinical parameters rather than rigid time thresholds [2,6,10,13]. It aligns with recommendations from recent expert commentaries, which emphasise that OTE should be pursued only when clear physiological readiness is achieved and appropriate rescue systems are in place. Our experience suggests that adopting a physiology based framework may help maintain safety while maximising the benefits of ultrafast extubation anaesthetics.

Despite its advantages, OTE is not suitable for all cardiac surgical patients. In our cohort, feasibility was lacking in combined CABG + valve procedures, complex redo surgeries, and cases with prolonged CPB and cross clamp times. These clinical scenarios often involve greater physiological stress, higher risk of low cardiac output syndrome, and increased likelihood of postoperative bleeding or arrhythmias. Similarly, patients with poor preoperative ventricular function, severe pulmonary hypertension, or significant comorbidity may be better managed with a delayed extubation strategy that allows closer monitoring and gradual weaning to avoid heroic act. The reported literature underscores that inappropriate attempts at OTE in high risk patients can lead to increased reintubation, respiratory complications, and worse outcomes. For these reasons, OTE should remain a selective strategy applied to carefully chosen patients within an experienced multidisciplinary framework [2,5,7,9,14]. Our data support this position, and we concur with authors who argue that OTE should not be a universal target but rather one component of an individualised recovery pathway.

In small and resource-constrained health systems, ICU capacity is finite and often stretched with ventilator availability, and trained personnel, which are often the principal limiting factors for cardiac surgical productibility and healthcare resource utilization. Within this context, strategies that safely reduce postoperative ventilation times, facilitate earlier ICU discharge, and optimise patient throughout have major health system implications. Our study suggests that even partial implementation of OTE applied to approximately one-third of patients can contribute to more efficient ICU turnover, potentially enabling treatment of additional cases without expansion of physical infrastructure. While we did not perform a formal cost analysis, previous economic evaluations have demonstrated that OTE and early extubation can reduce hospital costs through shorter ICU and ward stays and lower resource consumption. For resource-limited programmes, these benefits may translate into greater capacity to provide local cardiac surgery and reduced need for referrals abroad.

## Limitations

Several limitations must be acknowledged. First, this was a single-centre retrospective observational study without a contemporaneous control group matched for baseline risk, which limits causal inference. Selection bias is likely, as OTE was more readily offered to lower risk patients and to less complex procedures, and we did not perform risk adjusted comparisons between OTE and ICU extubation groups. Second, the sample size particularly within the OTE subgroup is modest, precluding robust multivariable analysis of predictors and outcomes.

Third, we did not systematically collect data on postoperative pain scores, opioid consumption, patient satisfaction, or detailed functional recovery measures, which would have provided further insight into the contribution of ESPB and the broader enhanced recovery framework.

Fourth, our findings may not be generalisable to centres with different case mix, staffing models, or ICU resources. Nonetheless, the study provides pragmatic, real-world evidence that OTE can be safely incorporated into a developing cardiac surgical programme in a resource-limited setting.

Future studies should aim to prospectively evaluate OTE within a structured enhanced recovery after cardiac surgery pathway, incorporate formal risk stratification, and include patient centred outcomes such as pain, quality of recovery, and satisfaction. Randomised or propensity matched studies comparing physiology based OTE with conventional fast track extubation would further clarify which patients benefit most from ultrafast strategies and how to safely expand adoption.

## Conclusions

On-table extubation is a feasible and apparently safe strategy in selected cardiac surgical patients within a newly established, resource-limited cardiac surgical programme in the Maldives. When supported by a structured anaesthetic protocol, multimodal analgesia including ESPB, routine TEE assessment, and clearly defined physiological extubation criteria, OTE can be achieved in approximately one third of patients without OTE-related mortality and with an acceptable reintubation rate. OTE should, however, remain a selective and individualised approach rather than a universal extubation endpoint, particularly in patients with complex procedures, prolonged CPB or cross clamp times, or significant ventricular dysfunction. In resource constrained settings, partial adoption of OTE has the potential to enhance ICU productibility, reduce reliance on prolonged mechanical ventilation, and support the sustainability of local cardiac surgical services. Further prospective, risk adjusted studies are warranted to validate these findings, refine selection criteria, and explore long term clinical and economic outcomes associated with OTE in similar environments.

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