ABSTRACT

PATTERNS OF INSTABILITY ASSOCIATED WITH ENDOTRACHEAL SUCTIONING IN INFANTS WITH SINGLE VENTRICLE PHYSIOLOGY

Background

In infants with single ventricle physiology endotracheal suctioning poses greater risks due to the instability between pulmonary and systemic blood flow.

Objective

To examine processes and adverse events associated with endotracheal suctioning in the first 48 hours post-operatively after three specific surgical procedures: Norwood or Norwood Sano, Pulmonary Artery banding and Modified Blalock-Taussig Shunt.

Methods

A prospective observational study in a single Pediatric Intensive Care Unit.

Results

Two hundred and eleven (211) episodes of bedside nurse endotracheal suctioning data were collected in 24 infants. Sixty-two per cent (130/211) of these suction episodes were classed (by the nurse) as unplanned and 38% (81/211) planned. Reasons cited for the unplanned suctions were most commonly (48% 62/130) acute arterial desaturation. However, the level of oxygen saturation prior to suctioning (for 'desaturation') ranged from 27% - 86%. A serious adverse event (SAE) occurred in 9% (19/211) of suction episodes. In the 19 suction episodes where a SAE occurred, 42% [8/19] did NOT have an additional intravenous bolus of analgesic or relaxant pre-suction and three of these were planned suctions. However, 42% [8/19] had both drugs pre-suction, 3/19 (16%) had either a relaxant but not an analgesic or vice versa. 74% [14/19] of adverse events occurred with open suction, 26% (5/19) with closed suction and 68% (13/19) occurred on the night shift 7pm – 7am.

Conclusions

Data collected by bedside nurses during their routine endotracheal suctioning, demonstrates significant hemodynamic instability and adverse events. It was notable that unit clinical guidelines were not always adhered to by bedside nurses.

INTRODUCTION

Endotracheal suctioning (ETS) is one of the most common nursing interventions undertaken in the Pediatric Intensive Care Unit (PICU) and is an essential part of the care of the intubated child, to prevent tube occlusion [1]. A number of studies have described adverse events associated with endotracheal suction, including hypoxemia, bradycardia, pneumothorax, airway trauma, cardiac arrest [2], but none have described the impact of the procedure in infants with single ventricle physiology following surgical palliation. The aim of this paper is to describe the process and impact of endotracheal suctioning in such patients in the first 48 hours after surgery.

BACKGROUND

In the United Kingdom (UK), three surgical procedures continue to have the highest early mortality, Classic Norwood or Norwood Sano (NS), Pulmonary Artery banding (PAB) and Modified Blalock-Taussig Shunts (MBTS) [3]. These surgical procedures are undertaken primarily in infants with a single ventricle physiology. This abnormality of this circulation is extreme, and having only one functional ventricle (from a number of different congenital abnormalities) leads to either increased pulmonary blood flow, reduced pulmonary blood flow and or an obstruction to systemic outflow, all of which are life-threatening[4]. In this critical period, soon after birth, one of these surgical interventions must usually be undertaken to stabilize the infant and provide a secure balance between pulmonary and systemic blood flow [5]. Thus, the objective of these surgical procedures is to produce a favorable longer -term relationship between pulmonary and systemic blood flow. This relationship remains unstable immediately after surgery, and this population have a higher incidence of adverse events during this early post-operative period [6,7] are likely to be related to this instability which is unique to this group of patients. This phenomenon is characterized by the ratio of pulmonary blood flow (Qp) to systemic blood flow (Qs). Low Qp:Qs will manifest as low arterial saturation, whilst high Qp:Qs will put an additional load

upon the abnormal heart. Very high Qp:Qs (associated by arterial saturations greater than 85%) is unsustainable, and will lead to heart failure, inadequate systemic blood flow, organ dysfunction and myocardial ischemia [4]. Immediately following surgery high Qp:Qs is common. This relationship, is, however quite dynamic and may be altered by minor changes in the child's condition such as temperature changes, inotrope dose alterations, pain and distress, sedation and opiate boluses, administering high concentration oxygen or noxious airway procedures such as endotracheal suctioning [8,9].

METHODS

A prospective observational study was undertaken as part of a larger randomized crossover study of open versus closed endotracheal suction in these children. As part of this, bedside nurses were asked to collect data on all their suction episodes undertaken in the first 48 hours post-operatively. Children were excluded if they were on Extracorporeal Membrane Oxygenation (ECMO) or if the parents declined consent for the larger study.

Objectives

The objective of this study was to examine processes and adverse events associated with bedside nurse-conducted endotracheal suctioning in the first 48 hours post-operatively after three specific surgical procedures: NS, PAB or MBTS.

Setting and standard practice

The study was undertaken in a 23 bed mixed general and cardiac PICU in the North West of England between September 2014 and January 2016. The registered nurse (RN) to patient ratio is 1:1 for invasively ventilated children and 50% of the PICU nurses possess a qualification in pediatric critical care. Nurses in this unit look after all children, cardiac and general intensive care is not separate. However only nurses with a recognized pediatric critical care qualification are assigned as the primary bedside nurse for these children in the first 48 hours post-operatively. The unit has four specialist PICU respiratory physiotherapists

who undertake some of the endotracheal suctioning in daytime hours, but the majority of endotracheal suctioning is undertaken by the bedside nurses. Standard unit suctioning at the time of this study was open suction, but closed (in-line) suctioning was encouraged and could be used in these children, but suction method was determined by the bedside nurse's choice. The unit has detailed clinical guidelines for endotracheal suctioning in these children (Figure 1). In our unit, suctioning was done 'as required' and not routinely at certain times or frequency. In this study though nurses defined their suctioning as 'unplanned' meaning in response to an acute clinical change in the child's condition or 'planned' not in response to an acute clinical change . A serious adverse event (SAE) was defined in this study as: a cardiopulmonary arrest (requiring active chest compressions or emergency chest re-exploration in an infant with an open chest), emergency chest re-exploration, severe desaturation (below condition-acceptable limits for the infant), bradycardia and hypotension that all required immediate intervention. All infants received continuous infusions of opiate (Fentanyl) and sedative (Midazolam) drugs and most (68%) a continuous muscle-relaxant infusion (Rocuronium or Atracurium). In addition, all three of these drugs are prescribed on an 'as required' basis for the nurse to give an additional intravenous (IV) bolus if they think the child is under-sedated or pre-procedures.

Data collection

Bedside nurses completed a data collection form for every endotracheal suction episode they undertake in the first 48 hours after surgery. This included data on drugs administered, indication for suctioning, and whether the suctioning was 'planned' or unplanned, how many suction passes, 0.9% saline usage and volume, suction method and any adverse events and what these were with their subsequent treatment. A research nurse reminded nurses to record this data daily and clarified any ambiguous data with the bedside nurse. Nurses recorded their name on the data collection form so queries could be checked with them and values were also checked on the history of the Phillips Intellivue monitor at the event time.

Analysis

Data analysis was entirely descriptive, as per the aim of this descriptive study. Data were entered into Microsoft Excel and means, medians and dispersion data produced.

Ethical issues

This study was part of a larger randomized crossover study of open versus closed suction and written parental informed consent was obtained prior to data collection. Ethical approval (Institutional Research Board) was obtained from Liverpool East Research Ethics Committee (REC) Ref. 14/NW/10 and the Hospitals Research Department.

RESULTS

The completion of data for endotracheal suction episodes was high by the bedside nurses, with all known suctioning episodes having data recorded. Two hundred and eleven (211) episodes of bedside nurse endotracheal suctioning data were collected in 24 infants (Table 1). Twenty-one PICU-qualified nurses were assigned these patients and recorded the suctioning episodes, with a mean PICU experience of 10 years (Standard Deviation (SD 4.8).

Sixty-two per cent (130/211) of these suction episodes were classed (by the nurse) as unplanned and 38% (81/211) planned. In the majority, (85%; 179/211) of suction episodes nurses used an open suction method, and in 15% (32/211) they used closed. The mean volume of 0.9% saline used was 0.62mls (SD) 0.99) and the mean number of suction passes per suction episode was 2.3 (SD 1.1).

Reasons cited for the unplanned suctions were most commonly (48%; 62/130) for acute arterial desaturation (Figure 2) (with 77% 48/62 infants having arterial oxygen saturation (Spo2) ≤70%). In this cohort of patients optimal Spo2 levels are generally considered to be between 75 – 85% [4].However, the level of Spo2 prior to suctioning (for ‘desaturation’) varied considerably from 27% - 86%.

A serious adverse event (SAE) occurred in 9% (19/211) of suction episodes in ten (42%) patients and involved 15 nurses (8 acute desaturations, 1 hypotension, 3 desaturation combined with hypotension, 3 cardiac arrests and 4 bradycardiac events). Seven SAEs (and all 3 cardiac arrests) occurred in one infant (3 during one night shift) (Table 2). Unit guidelines require an additional intravenous (IV) bolus of opiate (Fentanyl) and muscle-relaxant to be administered pre-suction (Figure 1) yet this did not always occur. In the 19 suction episodes where a SAE occurred, 42% (8/19) did NOT have an additional IV bolus of sedation or relaxant pre-suction and three of these were planned suctions. However, 42% (8/19) had both drugs pre-suction, 16% (3/19) had either a relaxant but not a sedative or vice versa. Nearly three-quarters, 74% (14/19) of the adverse events occurred with open suction and 26% (5/19) with closed suction. Over half, 68% (13/19) occurred on the night shift (7pm – 7am). Ten of the 13 of the SAEs that occurred on the night shift occurred over the first post-operative night (Table 2).

DISCUSSION

There is no previous work published on the impact of endotracheal suction in this group of high risk children. Desaturation (requiring intervention) was the most common adverse event associated with ETS. This has been identified in non-cardiac term infants ventilated in Neonatal Intensive Care Units (NICU) [10] and in our group given that the baseline Spo2 is lower (around 75-85%) and pre-oxygenation may be dangerous (by reducing pulmonary vascular resistance (PVR)) it could be expected that desaturation may be more of a problem [5]. On a number of occasions this desaturation was combined with hypotension, which in children with a single ventricle circulation, shows the risks involved in airway procedures which alter both the pulmonary vascular resistance and systematic vascular resistance (SVR) and the inherent fragility of these infants. The SVR may fall as a result of the intravenous opiate bolus [11] which is believed to be desirable to blunt the sympathetic response to suction, but may come at a cost. Hand ventilation may also cause instability

both by reducing venous return and causing hypotension as well as by reducing carbon dioxide level (and consequently pulmonary vascular resistance) by giving a higher minute volume than the child was receiving on the ventilator, this could increase pulmonary blood flow, at the expense of systemic blood flow. The three cardiac arrests (in one infant) demonstrate how precarious this circulation can be in the early post-operative period and may be a reflection of the child's unstable pathology and not just endotracheal suctioning. Bradycardia alone (without desaturation), which occurred in 4 infants may reflect vagal stimulation, more commonly seen in neonates. More adverse events were associated with open suction, and that may be due to a number of potential factors. A period of disconnection of the child from the ventilator will cause a brief period of apnea, the variability in how the nurse manually ventilates the child in rate, tidal volume/pressure and positive end expiratory pressure (PEEP) are applied risks causing hypotension from reduced venous return or risks hyperventilation, thus reducing pulmonary vascular resistance and increased pulmonary blood flow at the expense of systemic flow.

However, this observational study was not intended to study the differences between open or closed suctioning, and our concurrently running randomized crossover trial of open versus closed endotracheal suction intends to answer this question. Generally, endotracheal suctioning is undertaken only when indicated (such as audible secretions, increasing carbon dioxide levels, acute arterial desaturation or reducing minute volumes)[12]and in the majority of our patients (62%) this was the case. However in these critically ill and unstable infants with a size 3.0 or 3.5mm endotracheal tube which can occlude more readily than larger tube sizes, and for whom this procedure is highly noxious, nurses frequently do suction periodically to ensure tube patency. This may not be evidence-based, but there is no research to support any particular approach to suctioning in these high risk infants and indeed much of the research related to endotracheal suctioning has been carried out in stable children or adults [13,14,15,16] .The argument for this practice is to control the procedure and mitigate risk, rather than suctioning 'reactively' under less than controlled

conditions. Thus the paradox exists for the bedside nurse who must weigh up the risks of suctioning against the potential risks of not suctioning with the associated build-up of secretions impacting on carbon dioxide level and subsequently pulmonary vascular resistance.

Our unit endotracheal suctioning guidelines were developed by the senior nursing, medical and physiotherapy team and implemented in 2012 to try to reduce adverse events associated with endotracheal suctioning. However, despite being present in every bed space and widely publicized amongst the nursing team, there were not always adhered to, specifically with regard to additional pre-suction prophylactic opiate and relaxant boluses. It may be that the nurses believed the infants to be adequately sedated and muscle relaxed already, although sedation level cannot be formally scored in a muscle-relaxed child [17]. The use of physiologic parameters such as heart rate and blood pressure also may not be a reliable indicator of sedation level in very ill infants on inotropes and some who are paced [18]. Inadequate sedation can contribute to instability with endotracheal suction during ETS through increased sympathetic stimulation. Although in our institution boluses of these drugs can be administered fairly rapidly by the bedside nurse, who has an ongoing medical order to administer these drugs on an 'as required' basis (through the infusion pumps on which the drugs are running). However, these drugs will take at least few minutes to exert their effects. It may be the nurse was also concerned about potentially inducing hypotension or other adverse effects of these drugs. There is a plethora of published work exploring why healthcare professionals do not follow clinical guidelines [19,20] and in this study we do not know why the nurses did not follow the guidance.

It may be an incidental finding that more adverse events occurred on the night shift, and as surgery occurs during the daytime in general, it may be that the least stable first 12 hours post-operatively is over the first night, in which most of these night-time SAEs occurred. There is little research into night shift culture in intensive care units, but other work on night shift nurses has found that there is a reduction in staff numbers, which may lead staff to

believe they have to ‘cope’, combined with fatigue may impact upon decision making [22] Permanent night shift staff often receive less in-service education, than day staff, but in this study none of the nurses worked only night shift.

Strengths and limitations

There are a number of limitations in this study that warrant mentioning, it was a single centre study, with relatively few patients included and with a mixture of surgeries. Bedside nurses recorded the events associated with suctioning which risks bias, however, to reduce the risk of inaccuracy; any ambiguous data was checked by the research nurse both objectively and with the bedside nurse. Despite these limitations, we had a high compliance with data collection which is a strength, as is the fact that this data reflects’ real life’ practice in the PICU and helps us to understand what really occurs, rather than just under controlled study conditions.

Implications for nursing practice

Pediatric cardiac intensive care nurses need to be mindful that endotracheal suctioning can produce significant hemodynamic instability in post-operative single ventricle infants and that whenever possible endotracheal suctioning should be planned early (using early indications of the need for suctioning) so that senior people are available, risks can be assessed and mitigated as much as possible. Having an agreed and consistent approach to suctioning in these children should reduce variability in technique and reduce risks; however we will review our guidelines with regard to urgent suctioning in these children. Further research should investigate how experienced ‘expert’ pediatric cardiac nurses assess and mitigate risk in endotracheal suctioning in these children.

CONCLUSION

This study has demonstrated that endotracheal suctioning in this group of single ventricle children can produce severe instability and even cardiac arrest. There is no published

241 research around suctioning, or indeed any other nursing intervention in these children.
242 Currently, much of pediatric cardiac intensive care nursing practice is based on experience
243 and intuition, rather than evidence, and this can only be addressed through further research.
244 It was notable that unit clinical guidelines were not always adhered to by bedside nurses,
245 even when these guidelines were developed in an attempt to reduce adverse events and
246 promote stability.

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