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Original Article

Transportation of patients following surgery for congenital heart disease: a process review prompted by the opening of a new hospital

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Abstract: The decision to extubate the trachea of patients in the operating room prior to transport must balance the relative risks and advantages of transporting patients with an unsecured airway versus the problems associated with maintaining sedation and tracheal intubation during transport. Children with congenital heart disease often benefit from early tracheal extubation and this has been the standard of practice at our institution. However, the recent expansion and opening of a new hospital increased the distance from the cardiac operating rooms to the cardiothoracic intensive care unit and provided an opportunity for us to further evaluate our clinical practice. In order to better understand our practice and prepare for the opening of the new hospital, we conducted a prospective observational quality improvement project to evaluate the hemodynamic and respiratory parameters of postoperative patients undergoing transportation both before and after the move to the new hospital. The study cohort included 115 patients who ranged in age from 2 days to 25 years and in weight from 2.2 to 104 kilograms. Our analysis showed no significant change in our practice of early tracheal extubation. We noted no clinically significant changes in the monitored physiologic variables, despite the increase in the overall transport time. We believe that this transition and the ongoing safety of our practice were facilitated by significant preparation prior to the move including transport simulations.

Keywords: Extubation, congenital cardiac disease, pediatrics, patient transportation, cardiac surgery, quality improvement

Introduction

The intra-hospital transport of critically ill patients is accompanied by many potential risks including hemodynamic instability, respiratory compromise, equipment failure and hypothermia [1]. In many cases, these problems may result in significant morbidity with resultant physiological derangements. An intra-hospital transport may involve the movement of endotracheally intubated patients from a critical care unit to the operating room, radiology suite or other diagnostic arenas. Patients are also transported from the operating room directly to the ICU after surgical procedures. For many of these patients, there is no consideration about tracheal extubation prior to transport; in fact, many are purposefully left with an endotracheal tube in place or one is placed solely to facilitate the transport and ensure airway stability.

Children with congenital heart disease often benefit from early tracheal extubation [2]. By achieving early tracheal extubation, the unwanted attendant adverse effects of endotracheal intubation and mechanical ventilation can be minimized. These consequences include the need for increased sedation, increased inotropic support, prolonged stay in the intensive care unit, increased medical costs, nosocomial infections, mechanical obstruction of the endotracheal tube and unplanned extubation [3]. Specifically, patients with Fontan physiology or

Table 1. Patient and physiologic variables for transport to the old and new CTICU

Parameters and variables	Old CTICU	New CTICU
Number of patients	62	53
Number and percent undergoing tracheal extubation in the operating room	47 (76%)	36 (68%)
Weight (kilograms)	16.6 ± 19.8	16.3 ± 20.2
Age at surgery (years)	3.9 ± 5.8	4.2 ± 7
Change in body temperature (°C)	0.4 ± 0.7	0.3 ± 0.6
Change in oxygen saturation (%)	0.9 ± 3.3	0.1 ± 2.7
Change in heart rate (beats/minute)	-1.3 ± 9.7	-3.3 ± 9.3
Change in mean arterial pressure (mmHg)	3.5 ± 13	2.7 ± 7.0
Change in end-tidal carbon dioxide (mmHg)	-0.5 ± 7.4	-1.8 ± 8.0
Total transport time (minutes)	3.7 ± 2.0	5.4 ± 1.9*

*$p<0.0001$ versus old CTICU.

those with a superior cavo-pulmonary anastomosis (Glenn anatomy) will have improved hemodynamic function and increased pulmonary blood flow with spontaneous ventilation.

Our hospital (Nationwide Children's Hospital, Columbus, Ohio) recently completed the construction and opening of a new 12 story, free-standing children's hospital. This expansion added 750,000 square feet of clinical space and increased our capacity to a total of 552 inpatient beds. As a result of this construction, the transportation time from the cardiac operating room (OR) to the new cardiothoracic intensive care unit (CTICU) was increased by a distance of 410 feet. This increased the transport time by approximately 3 to 5 minutes, which was nearly double the time of our previous transports.

The Heart Center at Nationwide Children's Hospital favors an early extubation pathway following surgery for congenital heart disease [4, 5]. With the opening of the new hospital and the increased transportation distance, delaying tracheal extubation for the purposes of transport was discussed, but it was decided that the continued practice of early extubation was in the best interest of our patients. In order to better understand the safety of our transport process from the OR to the CTICU, a quality improvement project was initiated to evaluate the hemodynamic and respiratory parameters of patients undergoing tracheal extubation before and after the move to the new hospital.

Methods

The institutional review board of Nationwide Children's Hospital reviewed and approved of our protocol before any data was collected. Prior to the move, several simulated transports were conducted with the entire team to identify any issues or barriers that might impact the safety of our patients. A prospective observational quality improvement study was conducted encompassing 3 months of transports to the old CTICU location and 3 months of transports after the CTICU relocation. All patients left the cardiac operating rooms and were transported directly to the CTICU. Patients were fully monitored during transport according to our standard practice. This includes a continually transduced arterial pressure waveform as well as continuous electrocardiogram and O_2 saturation by pulse oximetry. Endotracheally intubated patients were transported with the use of a bag-valve-mask device with a Mapleson attachment while tracheally extubated patients breathed spontaneously with supplemental oxygen delivered as needed via a facemask or nasal cannula. End-tidal carbon dioxide ($EtCO_2$) was continuously monitored during the transport process and was measured by a side-stream sampling infrared device from the nasal cannula or the elbow of the anesthesia circuit.

An independent observer recorded the variables of interest both prior to leaving the operating room and again upon arrival in the CTICU. These variables included: patient temperature, heart rate (HR), blood pressure (BP), O_2 saturation, respiratory rate (RR), $EtCO_2$ and whether the trachea was intubated or extubated. Any difficulties during transport were noted and the need for tracheal reintubation after admission to the CTICU were also recorded.

The variables for transport to the old and new CTICU were compared using a non-paired t-test.

Table 2. Patient and physiologic variables for transport of intubated and extubated patients

Parameters and variables	Old CTICU Intubated	Old CTICU Extubated	New CTICU Intubated	New CTICU Extubated
Number of patients	15	47	17	36
Weight (kilograms)	7.8 ± 11.6	19.4 ± 21.1*	5.7 ± 9.9	21.2 ± 21.9*
Change in body temperature (°C)	-0.1 ± 0.7	0.3 ± 0.7	0.5 ± 0.8	0.3 ± 0.5
Change in oxygen saturation (%)	-0.2 ± 4.1	1.3 ± 2.9	-0.5 ± 3.6	0.4 ± 1.9
Change in heart rate (beats/minute)	4.7 ± 13.6	-3.2 ± 7.3*	1.2 ± 4.9	-5.4 ± 10*
Change in mean arterial pressure (mmHg)	12.8 ± 15.4	0.8 ± 10.9**	7.3 ± 5.7	0.4 ± 6.3+
Change in end-tidal carbon dioxide (mmHg)	-2.4 ± 10.3	0.2 ± 6.1	-1.6 ± 7.5	-1.9 ± 8.2
Total transport time (minutes)	4.3 ± 2.5	3.5 ± 1.8	5.5 ± 1.7	5.3 ± 2.1

*P<0.05 versus intubated. **P=0.0014 for intubated. +P=0.003 for intubated.

The rate of tracheal extubation in the OR before and after the move was compared using a Fisher's exact test. All data are listed as the mean ± SD with P<0.05 considered significant.

Results

The study cohort included 115 patients who ranged in age from 2 days to 25 years and in weight from 2.2 to 104 kilograms. There were 62 patients enrolled prior to the move and 53 following the move. The demographic data and measured variables for the two groups are outlined in (**Table 1**). There was no difference in the percentage of patients undergoing tracheal extubation in the operating room following the move to the new CTICU (76% versus 68%). Other than the transportation time, no statistically significant changes in any of the recorded data were noted for patients transported either to the old or the new CTICU. Following the move, the transport time increased an average of 1.7 minutes (from 3.7 ± 2.0 to 5.4 ± 1.9 minutes, p<0.0001). There were no episodes of hemodynamic instability requiring resuscitation including the administration of fluid or vasoactive medications. There was no need for reintubation of the tracheal or other airway intervention in the patients. No other adverse outcomes over the course of the transportation were noted.

When comparing those patients who underwent tracheal extubation in the operating room versus those whose tracheas remained intubated, there was a statistically significant difference in the weight between these groups for both the old and the new CTICU (**Table 2**). There were no clinically significant changes in the hemodynamic or respiratory variables when comparing the transportation of tracheally intubated patients to those of tracheally extubated patients. However, we did note a statistically significant increase in the mean arterial pressure when comparing patients who underwent tracheal extubation in the operating room and those who did not (**Table 2**). This difference was present for both the old and the new CTICU.

Discussion

The safe transport of postoperative patients following surgery for congenital heart disease remains a key component to the successful outcome of these patients. The transport procedure involves transitioning from the convenience and comfort of the operating room to a dynamic process where the task of moving the patient is added to the usual routine of monitoring the patient's physiological variables and intervening as needed. During this time, it is paramount that the anesthesia provider's attention remains focused on the task of monitoring and that the needed equipment and medications are readily available should interventions be required. In our circumstance, we anticipated that the move to a new CTICU would lengthen the time required for this critical step of the perioperative process. This was determined by practice simulations which actually measured the transport time to the new CTICU. This provided us with needed information as we debated whether to adjust our usual clinical practice especially that of early tracheal extubation. The new transport route included moving patients from the 2nd floor where the operating room is located to the 4th floor (CTICU location). Although the old CTICU was also on the 4th floor, the route was changed as the new

CTICU was in an entirely new building. The new transportation route required an elevator transport as was previously the case and also passage through a corridor which thereby extended the transport time by approximately 2-3 minutes. As such, we decided that a prospective quality assurance process was indicated in order to track the outcomes and compare them to our previous transport practices.

The potential issues that may occur during transport are illustrated by the prospective review of Wallen et al. from a 50 bed Pediatric ICU [6]. The study encompassed a two phase process with phase one involving prospective data collection of adverse events which occurred during transport and phase two involving the test of the hypothesis that adverse events during transport were due to the transport process itself. Phase one of the study involved 180 transports in 139 patients while phase 2 included 89 transports in 85 patients. Although there were no cardiac arrests or deaths during transport, there was a significant change in at least one physiological variables in 71.7% of transports and at least one equipment-related mishap in 10% of transports. At least one major intervention was performed in 13.9% of transports in response to physiologic deterioration or an equipment-related mishap. There was a significant correlation noted between the duration of transport as well as the severity of illness and the likelihood of the need for a major intervention and physiologic deterioration. The duration of transport was also associated with the potential for an equipment-related event.

The impact of the increase in transport time as well as the potential for adverse events may be further exaggerated in the immediate postoperative period following cardiopulmonary bypass where there may be ongoing issues with bleeding and other factors leading to cardiorespiratory instability. These issues may be further magnified by the current practice for such cases which involves early tracheal extubation. As such, vigilance is mandatory during the transport of these patients. Our standard process includes full monitoring of these patients during transport. A double-check of all equipment involved in transport including the battery on the transport monitor is completed prior to the transport. Airway management supplies, fluids, blood products and resuscitation medications are readily available during the transport, and organized in red tackle boxes.

The transport team includes at least two members of the anesthesia team, an anesthesia technician, perfusion personnel, members of the surgical team, and nursing staff. As such, there is ample help in the event that any such issues arise. Additionally, the anesthesia provider's only task is maintaining the airway, monitoring the physiological variables of the patient, and intervening as needed. There are other members who are responsible for movement of the patient's bed and the physical aspects of patient transport. As has become common practice in most institutions, upon arrival a detailed hand-off using a predetermined script with written documentation is provided to the CTICU staff including the bedside nursing staff, CTICU physician attending, and advanced practice nurses [7]. The newer generation of monitors may also facilitate and expedite the transport as they can be removed from the cartridge in the operating room and used during transport thereby allowing the uninterrupted monitoring of these patients as well as the collection of data for future review.

In comparing, patients who underwent tracheal extubation in the OR with those who did not, it was noted that there was a weight difference. This is not unexpected as the majority of patients who require tracheal intubation postoperatively are neonates and infants who have prolonged or complex surgical procedures. We also noted a statistically significant difference in the change in mean arterial pressure in both the old and the new CTICU between patients who underwent tracheal extubation and those who did not. The increase in MAP and slight increase in HR noted for patients with postoperative tracheal intubation is consistent with the need for additional sedation as the volatile anesthetic agent dissipates during the immediate postoperative period. These increases result in additional myocardial work and oxygen consumption, both of which are undesirable following surgery for congenital heart disease especially following the ischemic effects of aortic cross-clamping and other factors which may result in depressed myocardial function. Although it did not meet statistical significance, the other potentially clinical significant differ-

ence was that the $EtCO_2$ was lower in tracheally intubated patients. Inadvertent hyperventilation may occur during hospital transports in patients ventilated with a bag-valve-mask device [8]. Use of a transport ventilator, which may provide a more precise control of the $PaCO_2$, may be considered in patients with increased intracranial pressure, pulmonary hypertension or single ventricle physiology [9].

Despite the increase in the transport time with the opening of a new CTICU, we did not note any significant change in the safety of our transports or our practice of early tracheal extubation in our pediatric cardiac operating rooms. We believe that this transition was facilitated by significant preparation prior to the move including transport simulations. Early tracheal extubation continued to occur in approximately 68% of our cases as compared to 76% prior to the move. Our current quality assurance project has reinforced this practice showing no clinically significant difference in hemodynamic or respiratory stability in the patients being transported to the old versus the new CTICU.

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Disclosure of conflict of interest

None.

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