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Reduced length of stay after implementation of a clinical pathway following repair of ventricular septal defect

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Abstract

Background: There is variation in care and hospital length of stay following surgical repair of ventricular septal defects. The use of clinical pathways in a variety of paediatric care settings has been shown to reduce practice variability and overall length of stay without increasing the rate of adverse events. *Methods:* A clinical pathway was created and used to guide care following surgical repair of ventricular septal defects. A retrospective review was done to compare patients two years prior and three years after the pathway was implemented. *Results:* There were 23 pre-pathway patients and 25 pathway patients. Demographic characteristics were similar between groups. Univariate analysis demonstrated a significantly shorter time to initiation of enteral intake in the pathway patients (median time to first enteral intake after cardiac ICU admission was 360 minutes in pre-pathway patients and 180 minutes in pathway patients, $p < 0.01$). Multivariate regression analyses demonstrated that the pathway use was independently associated with a decrease in time to first enteral intake (−203 minutes), hospital length of stay (−23.1 hours), and cardiac ICU length of stay (−20.5 hours). No adverse events were associated with the use of the pathway, including mortality, reintubation rate, acute kidney injury, increased bleeding from chest tube, or readmissions. *Conclusions:* The use of the clinical pathway improved time to initiation of enteral intake and decreased length of hospital stay. Surgery-specific pathways may decrease variability in care while also improving quality metrics.

Variation in treatment and inconsistent care may affect quality of care and specifically length of stay for paediatric patients in the hospital setting. Reducing variability in care can assist in creating consistent outcomes for patients following cardiac surgery. Optimizing that care plan may also improve outcomes. The use of clinical pathways in a variety of paediatric care settings has been shown to reduce overall length of stay without increasing the rate of adverse events.[1,2]

Interprovider variability can account for variation in care following surgery, as well as extended length of stays.[2] Longer postoperative length of stays account for increased hospital costs,[2,3,4] an increased risk of hospital acquired infections, as well as errors and worse long-term neurodevelopmental outcomes.[1,2]

Clinical pathways aimed at decreasing inter-provider variability have been used for several years and have been associated with reductions in morbidity, mortality, resource usage, and hospital length of stay.[2,5,6] Clinical pathways have also shown to improve patient care in a variety of patient-specific settings.[1,2,3] There has been some study of reducing hospital length of stays following cardiac surgery using problem specific pathways such as feeding advancement.[7] However, surgery-specific pathways offering a more complete guide to post-operative care may further reduce length of stays, but are rarely described in recent literature.

We organised a small cohort of providers and nursing staff to build a surgery-specific fast-track clinical pathway for patients following ventricular septal defect repair. After establishing the pathway, we retrospectively compared a historical control of patients with ventricular septal defect repair prior to pathway usage and compared them to patients whose care was managed with the clinical pathway. Our hypothesis was that the introduction of a pathway would reduce variability in clinical outcomes and reduce length of stays.

Methods

We created a clinical pathway to care for patients following surgical ventricular septal defect repair with the guidance of a small, interprofessional, task force. The initial framework for the clinical pathway was based on standard of care and group consensus as well as evidence-based care.[8,9,10,11,12] The pathway was then approved by the entire provider and nursing leadership team in the cardiac ICU. The draft protocol was used with a number of patients prior to formal implementation. We then implemented the pathway as a tool to guide care following ventricular septal defect repair. Education was carried out on a monthly basis with each new set of rotating providers, as well as regular updates at faculty meetings. The outpatient cardiologists were also included in education on the pathway to assist in managing parental expectations of care and hospital length of stay.

This clinical pathway included timing of when milestones in care should be achieved. Important aspects of this pathway include (1) early extubation in the operating room or within six hours of cardiac ICU admission, (2) early enteral intake allowed (as early as two hours after admission), (3) early initiation and maintenance of scheduled furosemide (starts three hours after admission), (4) use of only as needed opioid analgesics rather than a continuous infusion with transition to enteral as early as the first postoperative night, (5) avoidance of continuous sedative medications such as midazolam or dexmedetomidine, (6) scheduled adjunct medications for pain control (ketorolac within 6 hours of admission and scheduled acetaminophen), (7) weaning oxygen therapy expeditiously, and (8) early mobilisation with urinary catheter removal no later than post operative morning one.

This retrospective historical control study took place at Advocate Children's Hospital, in Oak Lawn, Illinois. Institutional Review Board approval was obtained. All patients consecutively who had simple ventricular septal defect repair were evaluated for inclusion. Pre-pathway patients were identified from a surgical database for two years prior to implementation of the pathway. Four patients were excluded during a washout period as we tested the initial protocol. After 3 years of implementation, all patients post-ventricular septal defect repair were identified for the post-implementation group. Inclusion criteria were (1) patients ages 0–18 years and (2) ventricular septal defect repair, including patients who also had a patent ductus arteriosus ligation and/or the closure of an atrial septal defect. Exclusion criteria included: (1) patients over 1 year of age with an unrestrictive ventricular septal defect prior to repair (due to this population having higher risk for pulmonary hypertension), (2) patients with other cardiac defects beyond patent ductus arteriosus and atrial septal defects, (3) prematurity defined as gestational age less than 36 weeks at the time of repair, (4) patients with chronic kidney disease, (5) patients with a genetic syndrome other than trisomy 21, (6) significant non-cardiac diagnosis (such as tracheostomy, use of gastrostomy tube, severe neurologic impairment, heterotaxy), and (7) patients intubated longer than 6 hours following cardiac ICU admission as the pathway has milestones that would limit timely achievement in patients with prolonged intubation. These same inclusion/exclusion criteria were used for patients selected from the baseline period and after implementation of the pathway.

Data were collected from the electronic medical records that included demographics, surgical repair, and outcomes, such as time to first enteral intake, need for re-intubation, etc. Milestone data were identified as the achievement of a particular protocol recommendation that was completed within the recommended time frame and was evaluated prospectively. There were a total of 43 possible milestones within the overall pathway, not all were applicable to each patient, as the pathway was used on varying age groups. Additionally, five milestones thought to be critical to pathway success were separately evaluated. These critical milestones included: the ventricular septal defect surgery performed as the first surgical case of the day and arriving to the cardiac ICU prior to 1400, administration of the first dose of furosemide within 4 hours post-operatively, initiation of enteral feedings within 4 hours, transition to enteral pain control by the morning following surgery, and no initiation of continuous sedation or opioid infusions. We did not distinguish between the provider not achieving the milestone in the recommended time period due to the patient's condition versus non-compliance to the pathway.

Descriptive variables are described as absolute frequency and percentage. Continuous variables are described as median and range. Patients were divided into two groups: those cared for before and after the institution of the clinical pathway. Descriptive variables were compared between the groups using Fisher exact tests, while continuous variables were compared between the groups using a Mann–Whitney U test.

Next, a series of regression analyses were conducted. First a linear regression was conducted in stepwise fashion with time to enteral intake as the dependent variable. Next, a linear regression was conducted with ICU length of stay as the dependent variable. Finally, a linear regression was conducted with postoperative hospital length of stay as the dependent variable. The following independent variables were entered into the regression analyses: weight at time of operation, cardiopulmonary bypass time, cross clamp time, inotrope score, peak lactate, pre or post-pathway. All regressions were conducted in a stepwise fashion.

All statistical analyses were conducted using SPSS Version 23.0. A p-value of less than 0.05 was considered statistically significant. Any use of the word "significant" or "significance" in this manuscript implies statistical significance unless explicitly stated otherwise.

Results

Sixty-four patients were evaluated for inclusion in the pathway data, and 16 patients were excluded from the data collection. Four patients were excluded due to genetic anomalies other than trisomy 21, such as DiGeorge syndrome and Noonan syndrome. Seven patients were excluded due to cardiac lesions present aside from a ventricular septal defect, atrial septal defect, or patent ductus arteriosus, such as pulmonary stenosis, aortic stenosis, and a cleft mitral valve. Two patients were excluded due to prematurity requiring hospitalisation since birth and no discharge prior to surgical repair. Three patients were excluded due to extracardiac anomalies such as tracheoesophageal fistula and heterotaxy syndrome. A total of 48 patients were included in the final analyses. Of these, 23 patients underwent surgical ventricular septal defect closures prior to implementation and 25 patients following implementation of a clinical pathway. The pre-implementation group data were collected, with the earliest patient data reviewed in January 2016. The pathway was implemented in January 2018, and data were reviewed for patients through December 2020. Demographic data including age, gender, and weight did not differ between the two groups (Table 1). Perioperative factors including cardiopulmonary bypass time and cross clamp time also did not differ between the two groups. There was an 82% rate of achievement of all possible milestones prescribed in the pathway. Amongst the milestones deemed critical, 80% of the milestones were achieved. The most common reason for lack of achievement of milestones is delay in initial administration of furosemide.

Inotrope score and peak serum lactate did not differ between the two groups. All patients in the pre- and post-implementation groups were extubated intraoperatively. Time to first enteral intake was significantly lower in patients cared for after pathway implementation (180 versus 360 minutes, $p < 0.01$) (Table 2). Total postoperative hospital length of stays was significantly shorter in patients cared for after pathway implementation (50 hours versus 70 hours, $p = 0.04$). There was no significant difference in need for readmission.

Table 1. Characteristics between those who underwent ventricular septal defect closure before and after the introduction of the clinical pathway

	Before pathway (n = 23)	After pathway(n = 25)	p-value
Gender (2)	16	22	0.16
Weight	8.0 (4.0–53.8)	6.9 (4.1–88.3)	
Cardiopulmonary bypass time	62 (33–150)	57 (42–97)	0.66
Cross clamp time	49 (21–131)	40 (24–68)	0.21
Inotrope score	0 (0–10)	5 (0–10)	0.15
Peak lactate	2.8 (1.5–8.6)	2.7 (1.5–9.3)	0.90
Time to feeding (minutes)	360 (120–1320)	180 (90–1245)	< 0.01
Emesis with feeds	4	8	0.32
Total ICU length of stay (hours)	31 (26–179)	33 (23–58)	0.65
Total postoperative hospital length of stay (hours)	70 (44–218)	50 (26–121)	0.04
Readmission	1	0	0.47

Table 2. Percent compliance for critical milestones of the clinical pathway

Critical Milestone	Percent of Patients Identified as Compliant
First Case/Out of OR by 1400	88%
Furosemide within 4 hours	20%
Enteral feeds within 4 hours	72%
Transition to enteral analgesia	80%
No continuous sedation/opioid infusions	84%

Multivariable regression analysis with time to first enteral intake as the dependent variable demonstrated that peak lactate (beta-coefficient = 75.1, $p < 0.01$) and the pathway (beta-coefficient = –203.4, $p < 0.01$) were significantly associated with time to enteral intake. Phrased differently, every 1 mmol/L increase in peak serum lactate was associated with a 75-minute increase in time to enteral intake and being operated on after implementation of the clinical pathway was associated with a 203-minute decrease in time to enteral intake.

Multivariable regression analysis with ICU length of stays as the dependent variable demonstrated that weight (beta-coefficient –2.0, $p < 0.01$), cardiopulmonary bypass time (beta-coefficient 1.6, $p = 0.02$), cross clamp time (beta-coefficient –2.1, $p = 0.04$), peak lactate (beta-coefficient 7.5, $p = 0.04$), and the pathway (beta-coefficient –20.5, $p = 0.03$) were significantly associated with ICU length of stays. Phrased differently, every 1 kg increase in weight was associated with a 2 hour decrease in ICU length of stays, every 1 minute increase in cardiopulmonary bypass time was associated with a 1.6 hour increase ICU length of stays, every 1 minute increase in cross clamp time was associated with a 2.1 hour decrease in ICU length of stays, every 1 mmol/L increase in peak serum lactate was associated with a 7.5 hour increase in ICU length of stays, and being operated on after implementation of the clinical pathway was associated with a 20 hour decrease in ICU length of stays.

Multivariable regression analysis with postoperative length of hospital stay as the dependent variable demonstrated that the pathway (beta-coefficient –22.7, $p = 0.03$) was significantly associated with reduced postoperative length of hospital stay.

Discussion

The introduction of a clinical pathway reduced the hospital length of stays for patients following ventricular septal defect repair by almost a day. There was also a reduction in time to first enteral intake with pathway usage. We presumed, given the high compliance in achieving milestones prescribed by the pathway that there was decreased variability in treatment plans for patients following ventricular septal defect repair.

DeSomma et al[6] studied the use of a clinical pathway for patients following atrial septal defect repair and found that the use of their pathway decreased hospital length of stays and resource utilization. This pathway includes daily goals for patient outcomes for the care team to achieve, starting on postoperative day 1 with a goal of discharge on POD 2. Our pathway functioned similarly by defining goals for patient management, but in a more specific time-frame, including the de-escalation of care the evening of surgery. We also found a reduction in length of stays using this method.

Of the milestones identified as critical, compliance rates were the lowest for the timing of administration of the first dose of furosemide and the initiation of a continuous infusion of dexmedetomidine. Furosemide administered after 4 hours post-operatively was considered non-compliant. Furosemide was typically administered early, but not always within this strict time frame. It is likely furosemide was administered earlier than during the historical comparison period. The non-compliance related to the use of a continuous infusion was meant for opioids, but was often marked off due to the use of dexmedetomidine. A primary focus of the pathway was to encourage lower opioid use, and the administration of dexmedetomidine is not ideal, but may not be as deleterious.

We used a very prescriptive approach to reducing variation and decreasing length of stays. Conversely, Shin et al[13] described benchmarking results and then displaying visual targets for a variety of care goals in patient care that encouraged the team to decrease variability and hospital length of stays. This approach resulted in decreased variability and mechanical ventilation time,

Cardiac ICU length of stays, and hospital length of stays. Shin et al[13] dispensed with the need to go through the process of building specific care plans and still improved outcomes without directing individual provider management.

Our study evaluated the use of a clinical pathway, which was presented via a checklist of time-specific guidelines. The prescriptive

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approach to our clinical pathway prevents the omission of important care components and encourages timely care delivery in an otherwise distracting environment. Additionally, this presentation of achievable goals may motivate the user to progress care forward at a rate not otherwise considered. Both target based and prescriptive approaches are useful in decreasing length of stays via individual methods of encouraging forward progression. Future research could attempt to delineate which type of patient population benefits more from target-based versus prescriptive post-operative care.

A prescriptive approach also allows for review of evidence-based or best practices to be incorporated into the unit culture. For example, a reduction in nil per os time for patients following ventricular septal defect surgery may decrease fluid overload as intravenous crystalloid fluids are stopped when enteral intake is starting, possibly decreasing excessive fluid administration requiring increased diuresis. Patient agitation postoperatively is often related to thirst or hunger, and may be difficult to identify in the non-verbal population. Increased agitation can contribute to increased sedative and opioid administration in the initial postoperative recovery period. This earlier progression of enteral intake may also lead to improved patient comfort at an earlier time, possibly decreasing sedative and opioid administration.

Additionally, the more rapid timeline of patient care may further improve provider comfort in fast-track methods of care, encouraging providers to use similar methods in varying patient populations. The use of faster care progression in this subset of patients following ventricular septal defect repair may benefit other patient populations with similar acuity post-cardiac surgery by reflecting these care techniques. This approach to patient management may further shorten hospital length of stay for a variety of CHDs.

Limitations

During the implementation phase, there was a unit bed expansion by 40%, high bedside staff turn-over, and hiring of new providers, nursing staff, and an additional cardiothoracic surgeon who started 70% of the way through the implementation phase. These additions may have led to variable degrees of knowledge and comfort in executing the pathway. The clinical pathway was printed for each patient and included a section that allowed for comments if the patient did not meet the goal within the identified time period. There was inconsistent documentation that highlighted these deviations from the pathway, making it difficult to determine if non-compliance was related to provider preference, incidental omission of forward progress, or patient clinical status.

Furthermore, the formulation of the clinical pathway encouraged providers and clinicians to focus on forward progression of patients and limitation of length of stay. Ongoing conversations surrounding length of stay regarding the pathway implementation could have led to a Hawthorne effect to decrease length of stay versus the use of the specific pathway guidelines.

Conclusions

The use of the clinical pathway improved time to initiation of enteral intake and decreased length of stay. Use of surgery-specific pathways may decrease variability in care while also improving quality metrics. There were no adverse outcomes related to the use of the pathway.

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Competing interest. None.

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