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Contents

Frog-Breathing Pattern: Pathognomonic Sign of a Tracheo-Subcutaneous Fistula

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Introduction: Surgical resection of thyroid cancer invading the trachea may cause injury to the tracheal wall, leading to tracheal fistula.[1] We report a patient who developed an unusual breathing pattern after thyroidectomy with partial tracheal resection. A subcutaneous air pocket on his neck inflated with each expiration and deflated with inspiration. Because only a stable tracheal window which remained open throughout the respiratory cycle could explain this breathing pattern, a diagnosis of a tracheal leak was made.

Case Presentation: Patient consent was obtained for publication of this case. A 68-year-old man with invasive thyroid carcinoma and worsening hypoxemia presented for emergent surgical neck exploration. Two days prior, he had undergone thyroidectomy, neck dissection, and resection of the first two tracheal rings. Medical history included hypertension and type 2 diabetes mellitus. Vital signs showed BP 155/88, pulse 104 /min, RR 22/min, SpO_2 87% with face mask oxygen at 8L/min, and temperature 37.9 degrees Celsius. His face was flushed and he displayed use of respiratory accessory muscles. With each expiration, the left anterolateral side of his neck inflated into a circular air pocket about 10 cm in diameter (A) which subsequently deflated (B) during inspiration, reminiscent of the breathing pattern of a frog. After intubation, it was impossible to visualize the tracheal fistula by bronchoscopy because the tracheal tube obstructed the fistula. Only after surgical exposure of the trachea that a 1.5 x 1.5 cm anterolateral tracheal wall fistula was revealed. Severe inflammation of the area along with copious bronchial secretions precluded tracheal anastomosis. A tracheostomy tube was inserted to secure the airway and enable effective tracheobronchial toilet. Decannulation occurred 18 days later.

Discussion: Anatomically, the frog-breathing pattern can only occur when a defect remains patent throughout the respiratory cycle to allow not only the exit but also the re-entry of expired air back into the tracheobronchial tree and lungs. Cartilaginous tracheal rings are rigid enough to keep the opening patent. In contrast, a perforation of the lungs, pleura, pharynx and esophagus may cause air leak leading to pneumothorax, mediastinal and subcutaneous emphysema.[2] Defects in these organs with flaccid walls collapse during inspiration and cannot account for the breathing pattern observed. Physiologically, the subcutaneous reservoir constituted a significant added dead-space from which rebreathing resulted in hypoxemia and hypercarbia manifested as tachycardia, cutaneous flushing and sweating. While expiration is mainly passive by chest wall recoil, inspiration requires greater effort to entrain air through a small opening. For every breath, the expired volume was slightly greater than the inspired volume. As the size of the air pocket enlarged, increased work of breathing precipitated respiratory failure. This repetitive characteristic frog-breathing pattern can make the diagnosis of a tracheo-subcutaneous fistula, even without confirmation by investigative diagnostic imaging.

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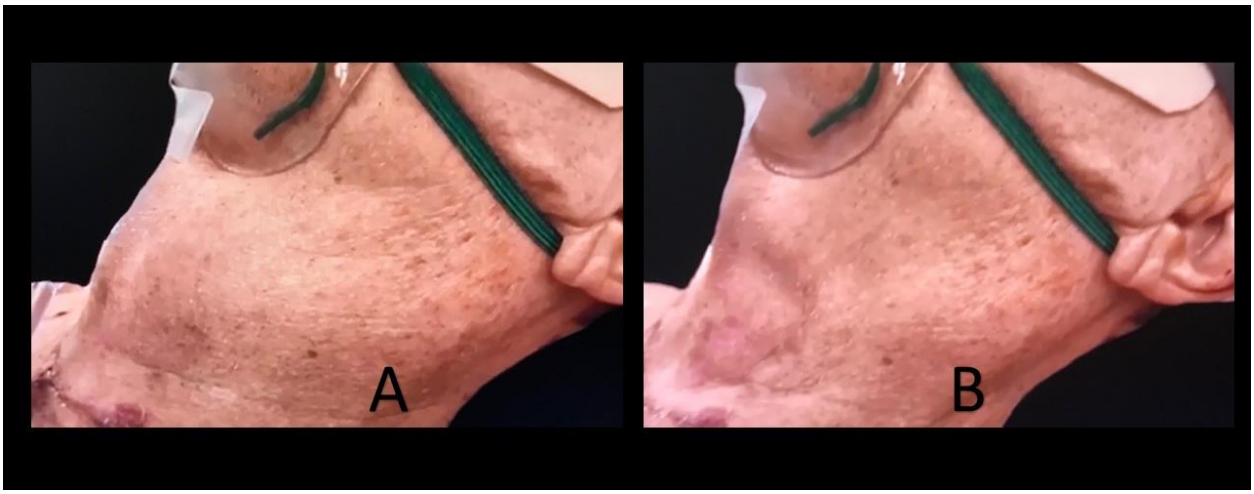

Heparin Activity Reversal Trial (HART): A Qualitative Analysis of (Anti)Coagulation Practices Among Cardiac Anesthesiologists at a Single Academic Centre

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Introduction: Clinical equipoise exists in the amount of protamine required to neutralize heparin during cardiac surgery.[1] Surgeons commonly ask for more protamine if there is ongoing hemorrhage, but anecdotally, it appears that cardiac anesthesiologists hold different rationales to decide how much is too much. Optimal control of hemostatis remains obligatory at this moment in the operating room or else the resultant hemorrhage and transfusions can not only be resource intesnisve but also have adverse outcomes.[2] Thus, the objective of this study was to explore the factors that influence cardiac anesthesiologists' decision-making for (anti)coagulation management in the cardiac surgery operating room. Understanding these may help increase homogeneity in clinical practice and may allow for development of written guidelines.

Methods: Ethics approval was obtained from the local REB. Following ethics approval and writen consent, 20 cardiac anesthesiology faculty members at a tertiary hospital setting were invited for semi-structured, in-depth, face-to-face interviews. Participants were asked questions about their practice of administering heparin and protamine. The interviews were transcribed and anonymized, then analyzed using NVivo (Version 12). Data collection and iterative anaylsis occured concurrently using Constructivist Grounded Theory methodology.

Results: Uncertainty about the required dose of protamine amongst anesthesiologsits was caused by paucity of evidence and lack of guidelines in clinical practice. Participants reported that absence of feedback about their postoperative patients in the Intensive Care Unit, as opposed to those transported to the Post Anesthesia Care Unit, impaired feedback on progress postoperatively. The learning culture at the institution was characterized by interprofessional collaboration with surgeons and perfusionists and dominated by peer influence. Appeasement with surgeons was common as were convenience and simplification strategies for (anti)coagulation management. Centre-specific practices evolved at the local institution and these were influenced predominantly by available monitoring equipment (or lack thereof) as well as a dominant peer influence. Participants thought that development of written guidelines would decrease conflict, update faculty and would serve as an educational tool for trainees.

Discussion/Conclusion: Clinical equipoise in the management of (anti)coagulation during cardiac surgery can be associated with evolution of centre-specific practices. Development of written guidelines for administration of heparin and protamine is perceived to have numerous beneficial effects for both trainers and trainees.

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Hypersensitivity Reaction During Endovascular Abdominal Aortic Aneurysm Repair with a Low Profile Stent

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Introduction: Eligibility for endovascular aneurysm repair (EVAR) can be limited by narrow access vessels or aneurysm neck anatomy. To address this limitation, novel low-profile stents have been developed. The Ovation Abdominal Stent Graft System (Endologix Inc., Irvine, CA) lacks the nitinol support which reduces the profile to a 14F outer diameter. Once the graft is deployed, inflatable rings are filled with a radiopaque polyethylene glycol (PEG)-based polymer. Deployment of the graft has been associated with polymer leak in 1/400 patients [1, 2]. Here, we present a case of profound hypotension due to polymer leak.

Case Presentation: Patient consent was obtained for publication of this case. A 67-year old male presented for EVAR to manage an abdominal aortic aneurysm (AAA). CT imaging revealed a 6.6 cm infrarenal AAA, severe atherosclerotic disease in the common iliac arteries, and thrombus within the aneurysm neck. The surgery was performed under general anesthesia with endotracheal intubation, a large bore IV, and arterial line. The Ovation stent was inserted and an angiogram was used to position the graft. The stent was deployed and polymer was injected. Approximately 12 minutes following polymer injection, the patient became profoundly hypotensive (BP 55/42) and tachycardic. Respiratory parameters and ECG were unchanged. There was no visible rash or wheeze. No hematoma or other sign of hemorrhage was identified. Anaphylaxis management was initiated including epinephrine, hydrocortisone, diphenhydramine, and IV fluid resuscitation. Diagnosis of polymer leak was confirmed. Four minutes following the initial reaction, the contralateral side was cannulated and a stiff wire was advanced through the graft. A Reliant stent graft balloon was then used to occlude the aorta in the supraceliac position. This was left inflated for 5-10 minutes, and slowly deflated once a perfusing blood pressure was achieved. Serum trypase at the time of the reaction and at the 1 hour timepoint were within normal limits. At the end of the case, vasopressors were no longer required and the patient was transferred to the ICU. He was discharged home on post-operative day 3.

Discussion: The risk of a polymer leak and hypersensitivity reaction with the Ovation graft is approximately 1/400. In the reported cases, 24/26 developed hypotension [2]. This reaction may be independent of IgE as tryptase was not elevated in our case. An anaphylactoid reaction should be considered with acute onset hypotension after polymer injection. Treatment should include management for anaphylaxis, and consideration of balloon occlusion of the aorta during resuscitation. To improve safety, the type of stent should be included in the surgical pause and injection of the polymer should be announced by the surgical team. We recommend arterial line access and large bore IV or central line access in all patients undergoing EVAR with a low-profile stent.

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Implementation of an Enhanced Recovery After Thoracic Surgery (ERATS) Program at an Academic Center

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Introduction: Lung cancer is the leading cause of cancer death in Canada[1]. Thoracic surgical procedures are associated with significant morbidity, mortality and hospital resources. Targeted initiatives to optimize care should be sought to minimize adverse events (AEs), length of stay (LOS), and improve flow of care. Enhanced recovery after surgery (ERAS) initiatives have demonstrated impact in multiple surgical domains; however, data on thoracic surgery is sparse, with only recent recommendations being made[2].

Objectives: To evaluate the effects of implementing a Division wide comprehensive Enhanced Recovery After Thoracic Surgery (ERATS) program on postoperative outcomes, processes of care, patient experience, and quality of life (QOL).

Methods: Ethics approval was obtained by REB. We conducted a prospective, longitudinal study evaluating 9 months pre and 9-months post implementation of an ERATS program. All patients undergoing the following procedures were included: anatomic pulmonary resection, esophagectomy, gastrectomy and giant paraesophageal hernia repair. Postoperative outcomes measured were: LOS, AEs, 30-day ER visits and readmissions. Process of care outcomes included time to: 'out-of-bed', independent ambulation, successful fluid intake, last chest tube removal, urinary catherization, removal epidural analgesia, discontinue patient-controlled analgesia (PCA). Compliance with ordering of multimodal analgesia and standardized anesthesia care were recorded. Patient satisfaction and QOL were measured in consenting patients.

Results: There were no differences in mean age, gender, or surgical procedures in either pre (n=349) or post-ERATS group (n=330). LOS was significantly shorter post ERATS (6.1 vs 4.5 days, $p<0.01$). There were no differences in Minor (18 vs 21.8%, $p=0.219$) or Major (13.8 vs 10%, $p=0.132$) AEs. For process outcomes, patients experienced shorter mean time to: 'out-of-bed' (18.3 vs 11.7 hours, $p<0.002$), independent ambulation (53.9 vs 40.3 hrs, $p<0.001$), successful fluid intake (30.3 vs 16.4 hrs, $p<0.013$), last chest tube removal (95.3 vs 76.7 hrs, $p<0.034$), and urinary catheter removal (50.9 vs 31.6 hrs, $p<0.001$) . There was no difference in the duration of epidural (87.4 vs 62.5 hrs, $p=0.06$) and PCA administration (45 vs 48.3 hrs, $p=0.209$) as well as 30-day ER visits (21.9 vs 14.5%, $p=0.051$) and 30-day re-admission (9.5 vs 5%, $p=0.081$). Following our recommendations, we noticed increased administration to appropriate patients of preoperative Pregabalin ((46.9 vs 62%, $p<0.001$) and intraoperative

Dexamethasone (76 vs 85.7%, p<0.001), but no difference in preoperative Celebrex use (62.7 vs 66.2%, p=0.398), protective one lung ventilation strategy (98.2 vs 99.7%, p=0.062), or muscle relaxant reversal (95 vs 96.2%, p=0.414). Average measures for patient satisfaction (88.4 vs 86.8) and QOL (42.2 vs 42.3) showed no difference between the two groups.

Conclusion: ERATS implementation significantly improved length of stay, expedited feeding, ambulation and tube removal, without increasing AEs or readmissions. Ongoing research will help further refine ERATS best practice.

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Lumbar Cerebrospinal Fluid Drain Complications in Patients Undergoing Open and Endovascular Thoracoabdominal Aortic Procedures

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Introduction: Acute or delayed paraplegia continues to be one of the most serious complications of thoracoabdominal aortic repair and is associated with significant morbidity and mortality. Although significant progress has been made over the past two decades, there is concern that the incidence of this complication may increase again due to lesser invasive repairs being undertaken in patients with significant comorbidities and more challenging aortic anatomy/pathology. One of the neuroprotective strategies employed to mitigate the risk of spinal cord injury (SCI) is lumbar cerebrospinal fluid (CSF) drainage which is employed to optimize spinal cord perfusion pressure (SCPP) and corresponding blood flow. While it is well established to reduce the incidence of SCI, it is associated with a range of potential complications. We examined the incidence of complications of lumbar CSF drainage in patients undergoing both endovascular and open approaches for the treatment of thoracoabdominal aortic diseases as well as the incidence of SCI in this population at our institution.

Methods: Following Institutional Research Ethics Board approval (which waived the need for patient consent), we performed a retrospective analysis of all patients who underwent open or endovascular repair of thoracoabdominal aortic disease in our Cardiac Sciences Program from 2005 (program inception) to August 2019. Descriptive statistics were used to outline the complications of lumbar CSF drainage (primary outcome) and the incidence of SCI.

Results: Of the 189 patients undergoing thoracic aortic procedures for acute and chronic aortic syndromes (including aneurysm, dissection, and a variety of other diagnoses), 89 (47%) had a lumbar CSF drain placed. Lumbar CSF drain complications occurred in 27 patients (30%). Of the 41 patients who underwent open surgical repair with lumbar CSF drainage, 7 (17%) experienced a complication attributable to the CSF drain, including 2 (5%) with an intracranial hemorrhage (ICH). Of the 48 patients who underwent endovascular repair with lumbar CSF drainage, 20 (42%) experienced a complication attributable to CSF drainage including 2 (4%) patients with an ICH. Five (6%) patients died from causes attributable to the CSF drainage. Spinal cord ischemia occurred in 22 patients (12%).

Conclusions: Lumbar CSF drainage is associated with serious complications. Our reported rates for each individual complication are consistent with those published in the current literature. However, our overall complication rate appears higher than that previously published, in part due to differences in definition of the various complications and completeness of reporting. Our institutional incidence of SCI appears consistent with that published in current literature.

Multi-View 3D TEE Volume Compounding for Mitral Valve Procedure Planning

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Introduction: Current standard of care diagnostic imaging for mitral valve procedures primarily consists of transesophageal echocardiography (TEE) as it provides a clear view of the mitral valve leaflets and surrounding tissue.[1,2] However, TEE has limitations in signal dropout and artefacts, particularly for structures lying below the valve such as chordae tendineae. As a result, multiple image acquisitions from multiple position along the esophagus must be made and viewed separately to observe all relevant structures. We propose a trackerless, volume compounding system to fuse mid-esophageal and transgastric 3D volumes to create a single ultrasound volume containing the mitral valve and sub-valvular structures with a high level of detail. This will enable the measurement of chordae length, which is required for procedures involving the implantation of artificial chordae.

Methods: Ethics approval was obtained from the local REB. Images were acquired from 2 patients during standard pre-operative imaging sessions using Philips Epiq TEE probes. One or more mid-esophageal volumes and four or more transgastric volumes with a high degree of overlap were acquired with ECG gating. These volumes are then rigidly registered with a semi-simultaneous group wise registration method[3] using the end-diastolic phase of the cardiac cycle. Following rigid alignment, for each frame in the image sequences, non-rigid registration is performed to account for slight variation in cardiac phase. The volumes are then resampled onto a common grid, and voxel-wise weighted averaging is used to generate the final output volume.

Results: We validated this image compounding approach on two excised porcine mitral valve units, a custom silicone phantom, and on two patient data sets. The porcine valves and silicone phantom were imaged according to our clinical acquisition procedure. The porcine valves were also stained with iodine and imaged with a CT scanner to provide ground truth data. The ultrasound images were then compounded using the described approach. The compounded volumes visually replicate the structures visible in the ground truth CT scan, and chordae measurements have an error of 0.6±0.5mm between modalities. Results of ultrasound compounding on patient data sets show clear delineation of the mitral valve leaflets, chordae tendineae, and papillary muscles.

Conclusions: We have described a workflow for capturing a series of images using a TEE probe during standard diagnostic imaging that can then be registered and compounded together. These compounded volumes capture the sub-valvular structures of interest for cardiac procedure planning. Capturing the necessary additional volumes can be done with only an additional ten minutes to the current standard of care diagnostic images with no modifcation of equipment. This method is able to provide clinicians with a single volume that captures the mitral valve and the sub-valvular structures, which will enhance the mitral valve procedure planning process.

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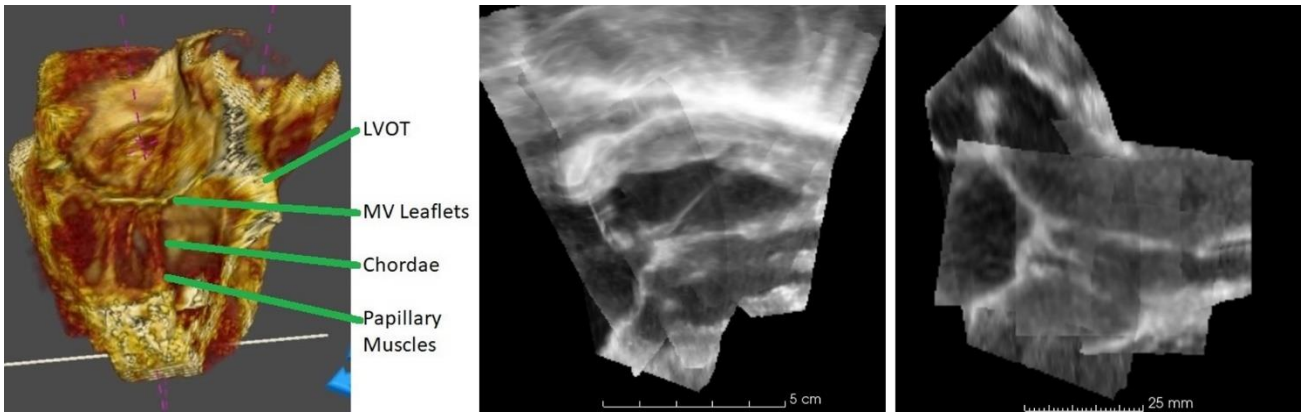

Non-Invasive Monitoring of CBF and Brain Oxidative Metabolism During Cardiopulmonary Bypass: A Novel Feasibility Study

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Introduction: Clinical management of brain-at-risk (BAR) patients is compromised by an inability to directly and non-invasively monitor cerebral blood flow (CBF) and oxidative metabolism (cytochrome C oxidase - CCO) continuously and non-invasively during surgery.[1] As the final common pathway for oxidative metabolism, changes in CCO represent the intersection of perfusion pressure, flow rate, oxygen content, and metabolic demand and reflect the adequacy or compromise of substrate delivery necessary to preserve neuronal function and brain tissue viability.[2] Advances in optical techniques have enabled real-time simultaneous monitoring of CBF and CCO by combining diffuse correlation spectroscopy (DCS) and broadband near-infrared spectroscopy (bNIRS).[3] This study is the first to assess the feasibility of employing these technologies in adult BAR patients during cardiopulmonary bypass (CPB).

Methods: Ethics approval was obtained from the local REB (#113650). 10 adult patients undergoing cardiac surgery with CPB were monitored intraoperatively with a custom built and newly modified DCS/bNIRS device[3] and hemodynamic and other biometric data were correlated to assess the impact of changes in CPB perfusion characteristics with changes in CBF and CCO.

Results: In all 10 patients, reliable signals from DCS and bNIRS device were obtained and were sufficient to demonstrate that decreases in perfusion pressure, perfusion flow rates and hemoglobin concentration had a variable impact on both CBF and CCO (see Figure). This study demonstrated diverse requirements for perfusion pressure and substrate delivery that varied between patients and within individual patients at differing times during surgery.

Conclusion: To our knowledge this study is the first such demonstration of the feasibility of using non-invasive optical devices to monitor changes in CBF and CCO in real time during CPB in BAR patients. It demonstrated variability in brain perfusion characteristics necessary to preserve CCO that differed between patients and over time in individual patients. This is further evidence of the importance of such individualized patient monitoring and represents an important first step in deploying such technology in various other high risk clinical situations.

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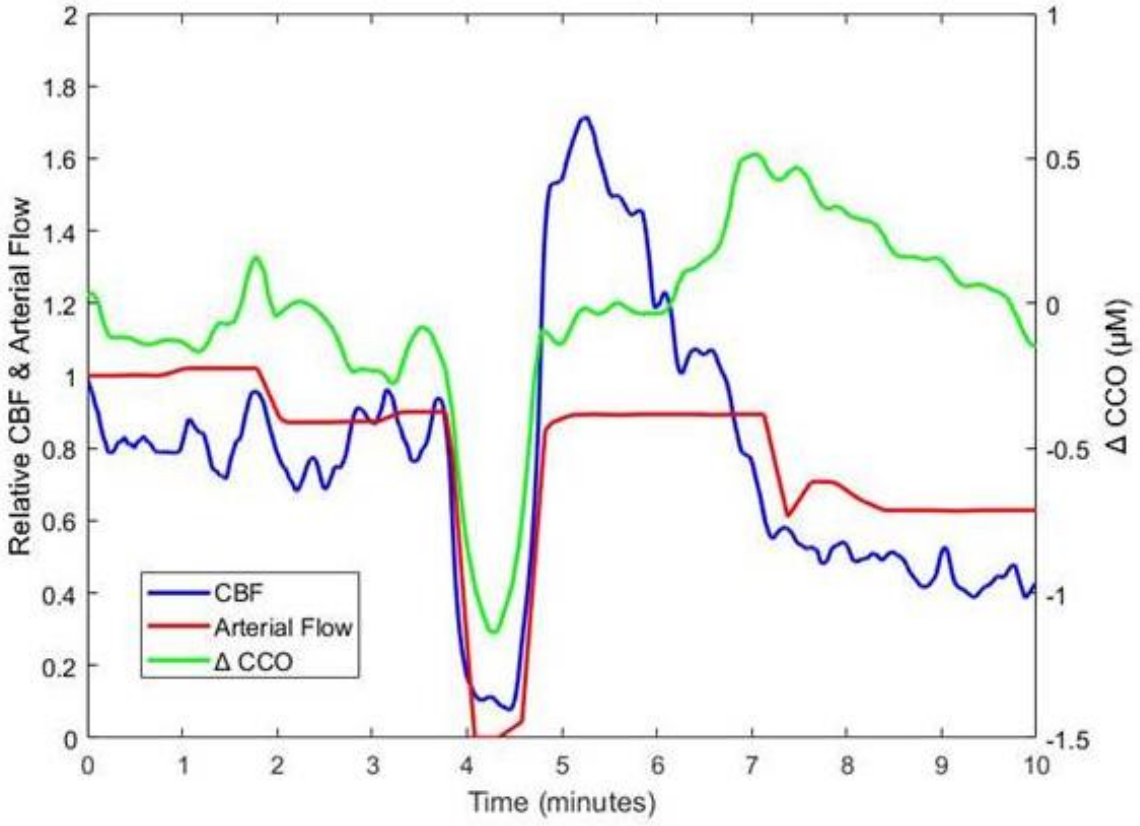

Continuous measures of CBF and metabolism (ΔCCO) during a hypoperfusion event during cardiopulmonary bypass, as measured by DCS and bNIRS. Arterial flow rate from bypass pump shown as change from baseline.

Rotational Thromboelastometry (ROTEM) Guided Use of Factor Concentrates in Cardiac Transplant Patients: A Retrospective Study

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Introduction: Orthotopic heart transplantation is performed as the last-line treatment for end-stage heart failure.[1] Due to a scarcity of donors, it is crucial to minimize postoperative complications and optimize patient outcome in every heart transplant case. Postoperative bleeding is one of the most common complications among patients undergoing cardiac surgery, oftentimes resulting significant morbidity and mortality.[2-4, 5] The etiology of perioperative bleeding is multifactorial – a combination of both patient and procedural factors. While blood transfusion in the setting of cardiac surgery is often necessary, it is associated with risks and complications including transfusion-related immunomodulation, transfusion-associated circulatory overload, transfusion error, sepsis, and transmitted diseases.[6] Therefore, effective hemostasis is crucial to positive patient outcomes. At our institution, our hemostatic transfusion practice has evolved from the administration of frozen plasma and cryoprecipitate given empirically or guided by standard laboratory tests (SLTs), to administering prothrombin complex concentrates (PCCs) and fibrinogen concentrate (FC) guided by rotational thromboelastometry (ROTEM). We have developed an institutional ROTEM-guided transfusion algorithm incorporating these changes to standardize concentrated hemostatic product administration.

The goal of this project is to compare ROTEM-guided administration of factor concentrates during cardiac transplantation to the administration of blood products based on empiric judgement and SLTs with respect to intraoperative hemostatic efficiency, postoperative bleeding, red blood cell (RBC) transfusion requirements, major adverse postoperative events, and length of stay.

Methods: Ethics approval was obtained from the local REB. All protocols were approved by UBC/PHCRI Research Ethics Board. Chart review was conducted for two cohorts of cardiac transplant patients, one of which received blood products empirically while the other followed a ROTEM-guided algorithm for administration of factor concentrates. Statistical analysis was performed using Mann Whitney U tests or Fisher's exact tests for continuous and categorical variables, respectively. The criterion for rejection of the null hypothesis was set at $p < 0.05$.

Results: ROTEM-guided transfusion of factor concentrates was able to reduce the time required for surgical hemostasis by 47.6% (163.3 vs 85.6 min, p= 0.0002), the total units of RBCs transfused within 24 hours post-surgery by 71.1% (9 vs 2.6 units, p=0.0032) and the total amount of bleeding via chest tube drainage by 55.5% (2254.5 vs 1002.4 ml, p=0.0073). There were no statistical differences between the two groups in terms of mortality or major complications. There was a statistically significant decrease in hospital length of stay (27.5 vs 14.9 days, p= 0.0482).

Conclusion: In cardiac transplant surgery, ROTEM-guided transfusion of factor concentrates improves intraoperative hemostatic efficiency, reduces postoperative bleeding and RBC transfusion requirements, and does not appear to increase the rate of major postoperative

adverse events. Larger studies are required to confirm the efficacy, safety, and benefits of this strategy.

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Strategies to Optimize Post-Operative Atrial Fibrillation: Amiodarone Prophylaxis Protocol Reduces New-Onset Atrial Fibrillation in Patients Undergoing Elective Cardiac Surgery

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Introduction: New-onset post-operative atrial fibrillation (POAF) is a relevant complication of cardiac surgery, increasing the risk of post-operative adverse events, length of hospital stay, health care costs, and mortality. Prophylactic prevention of POAF has been shown to decrease the economic burden after heart surgery. Despite this, the incidence continues to be 30%. A clinical prediction score (SOLV AFib) was derived to help prioritize preventative therapy for patients with moderate to high risk of developing POAF. Parameters included: age over 70, planned valve procedure, obesity, evidence of left atrial dilation, and a history of stroke.

Methods: Ethics approval was obtained from the local REB. This prospective cohort study (Feb 2016 – Dec 2018) consisted of three phases (baseline, implementation, post-implementation) to introduce a prophylactic amiodarone protocol for patients ≥18 years-old with no prior history of atrial fibrillation and undergoing elective CABG and/or valve surgery at a single center. Patients were screened using a SOLV AFib score threshold of ≥5 for eligibility to receive a target dose (4.8 g) of amiodarone, either orally 6 days before surgery (standard protocol) or intravenously at the time of surgery (accelerated protocol) (Figure 1). Patients were followed in hospital from surgery until discharge to document POAF, management and major complications. Summary statistics and univariate analysis (Chi-squared test of categorical variables and Student's T-test/ANOVA for continuous variables) with 95%CI's were reported for outcomes such as the incidence and burden of POAF, average dose of amiodarone given, and length of hospital stay.

Results: The number of patients included were: 1220 at baseline, 840 during implementation and 998 post-implementation. The groups did not differ significantly in demographics or risk factors for POAF. The protocol was started in 72% (152/212) of eligible patients during initial implementation and in 62% (113/182) after (95%CI 0.71%-19.15%, $p<0.05$). Preoperative loading of amiodarone reduced the incidence of POAF in patients that received protocol compared to those who were at a similar level of risk (SOLV Score ≥5) but did not receive protocol (from 55.0% (71/129) to 43.0% (114/265); 95%CI 1.51%-22.17%, $p<0.05$). The average hours spent in AF decreased from 49±3 hours pre-protocol to 36±3 hours during implementation and 35±3 hours post-implementation ($p<0.005$). Among patients on protocol, 49% (129/265) received at least the target dose. Patients on amiodarone prophylaxis did not have a significantly shorter length of ICU or hospital stay.

Discussion: Amiodarone prophylaxis can be useful for decreasing the incidence of POAF in higher risk patients. There was no significant decrease in protocol compliance 9 months after the initial implementation period. The lack of difference in ICU and hospital stay between the groups is likely related to incomplete loading of the amiodarone. Early discontinuation was primarily due to concerns of low heart rate and long QTc interval.

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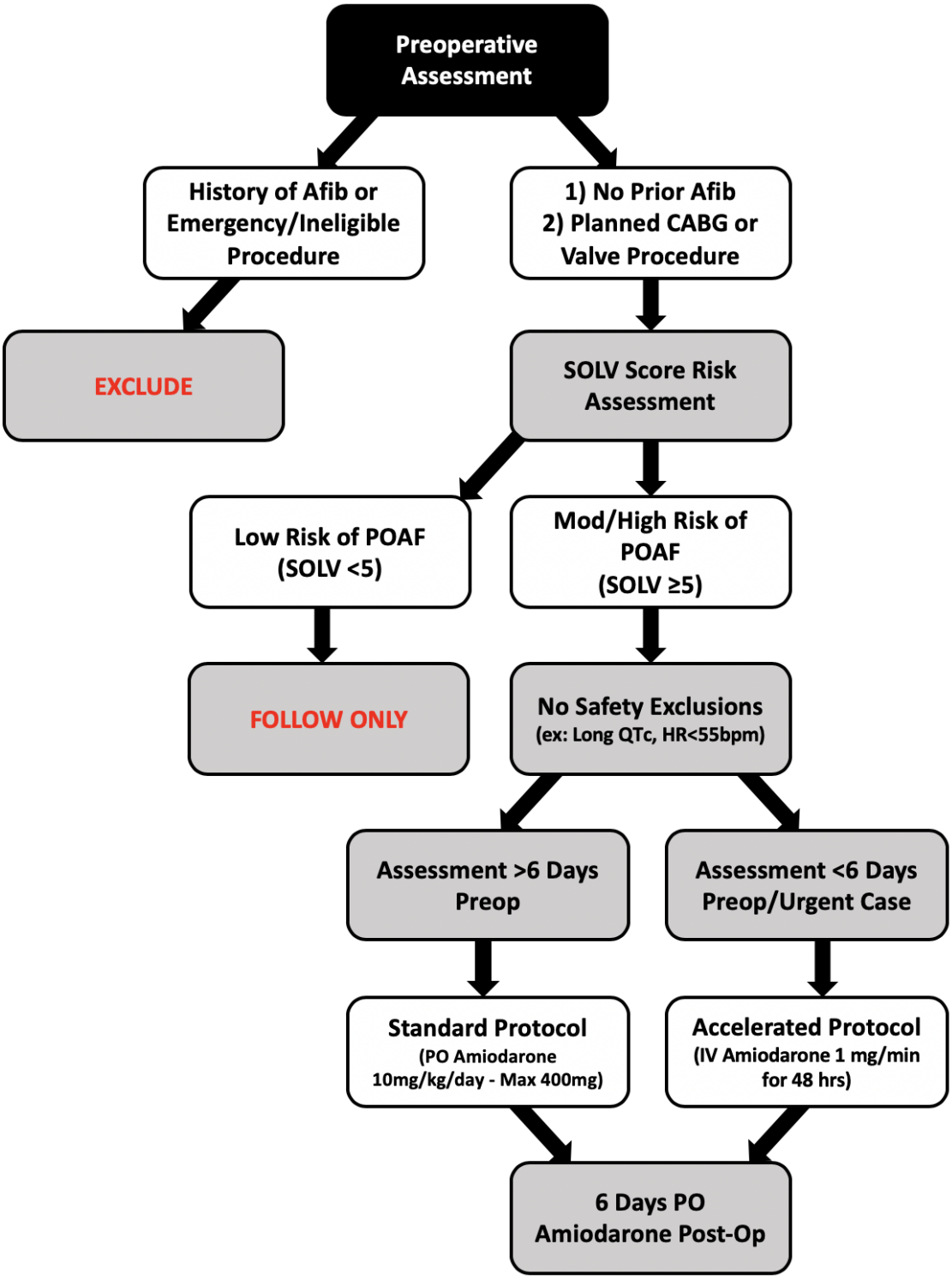
Preoperative Assessment
History of Afib or Emergency/Ineligible Procedure
1) No Prior Afib
2) Planned CABG or Valve Procedure
EXCLUDE
SOLV Score Risk Assessment
Low Risk of POAF (SOLV <5)
Mod/High Risk of POAF (SOLV ≥5)
FOLLOW ONLY
No Safety Exclusions
(ex: Long QTc, HR<55bpm)
Assessment >6 Days Preop
Assessment <6 Days Preop/Urgent Case
Standard Protocol
(PO Amiodarone 10mg/kg/day - Max 400mg)
Accelerated Protocol
(IV Amiodarone 1 mg/min for 48 hrs)
6 Days PO Amiodarone Post-Op