

# ETIOMETRY LITERATURE COMPENDIUM

The Etiometry Clinical Intelligence Platform supports clinicians in enhancing patient care and improving outcomes, particularly in critical care settings. The platform's sophisticated algorithms have undergone extensive validation in numerous studies, proving their reliability and effectiveness. A key feature of the platform is its focus on the ID02 and IVC02 Indexes, which helps identify early signs of patient deterioration, enabling healthcare providers to take proactive measures before conditions worsen. This approach also incorporates de-escalation strategies, enabling healthcare professionals to effectively intervene and manage the patient's condition, fostering a more seamless and efficient recovery process.

The Etiometry Quality Improvement Application (QI App) has supported more than 150 quality improvement initiatives and research projects, demonstrating the platform's role in enhancing healthcare delivery.

By harnessing the power of advanced analytics and real-time data, the Etiometry platform is playing a pivotal role in transforming critical care and driving measurable improvements in patient outcomes and healthcare delivery.

## DISCLAIMERS

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- The results presented in the studies are observational; the Etiometry Platform is intended to aid decision-making, not to independently improve outcomes.
- Some studies may refer to the Etiometry Platform as T3. In this Compendium we will use Etiometry Platform and T3 interchangeably.

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# CLINICAL IMPACT/OUTCOMES

## Clark, G. et al (2025) Automated spontaneous breathing trial performance tool is associated with improved outcomes following pediatric cardiac surgery: A single-center retrospective study from Alabama, USA

Journal of Pediatric Critical Care 12(1):p 1-7, Jan-Feb 2025.

[https://journals.lww.com/jpcr/fulltext/2025/01000/automated\\_spontaneous\\_breathing\\_trial\\_performance.1.aspx](https://journals.lww.com/jpcr/fulltext/2025/01000/automated_spontaneous_breathing_trial_performance.1.aspx)

### STUDY LIMITATIONS:

- Single-center study
- SBT has been used as an additional aid and didn't replace all other clinical assessments performed by the providers. It is possible that other variables contributed to the performance.

- Retrospective study of patients admitted to tertiary cardiac intensive care unit (CICU).
- 787 surgical hospitalizations were included, 581 preintervention and 206 postintervention. No significant differences in distribution of age groups, frequency of syndrome diagnosis, or surgical complexity between both groups.
- **SBT tool deployment was associated with a 30% reduction in postoperative Time on Ventilator (TOV)** (incidence rate for post-SBT tool is 0.7 times incidence rate for pre-SBT tool,  $P < 0.0001$ ) **and postoperative LOS by 20%** (0.81,  $P < 0.01$ ).
- Neonatal subgroup analysis ( $n = 145$ ) showed SBT tool implementation was associated with lower extubation failure, 0% versus 13% ( $P < 0.01$ ).
- The study concluded that deployment of physiology-based, real-time, automated SBT tool in a single pediatric CICU was associated with decreases in TOV and LOS as well as a decrease in extubation failure among neonates.

## Gazit, A.Z., et al (2025) Risk Analytics Clinical Decision Support Decreases Duration of Vasoactive Infusions Following Pediatric Cardiac Surgery: A Multicenter Before and After Clinical Trial

Critical Care Medicine 2025 • Volume 53 • Number 7

[https://journals.lww.com/ccmjournal/fulltext/2025/07000/risk\\_analytics\\_clinical\\_decision\\_support\\_decreases.1.aspx](https://journals.lww.com/ccmjournal/fulltext/2025/07000/risk_analytics_clinical_decision_support_decreases.1.aspx)

### STUDY LIMITATIONS:

- It is difficult to quantify the role of the Etiometry system. It is plausible that the act of implementing a new protocol by itself could have heightened clinicians' awareness of weaning vasoactive infusions, hence leading to more expeditious weans.

- Multicenter before-and-after study with a primary objective to quantify the effect of the Etiometry system, informed by inadequate delivery of oxygen index (IDO2), on inotropes and vasoactive infusions (IVAI) postoperatively.
- 3 pediatric cardiac ICUs (CICUs), infants  $> 36$  weeks and  $> 2$  kg following cardiac surgery with cardiopulmonary bypass, treated with IVAI  $\geq 6$  hours.
- Clinicians committed to consider data from the Etiometry system informed by 6 hours rolling IDO2 average in their plan to wean IVAI postoperatively. Within the system, documentation of decisions incorporating these data prompted patient inclusion in the intervention arm.
- Negative binomial and logistic regression models were used to assess differences between intervention and control groups.
- 343 patients were enrolled in the intervention group, and 432 patients were enrolled in the control group. The intervention group included a higher proportion of STAT 4 patients and a lower proportion of STAT 1 patients (81 vs. 62;  $p < 0.01$  and 43 vs. 108;  $p < 0.01$ , respectively).
- A risk-adjusted negative binomial regression model showed **29% shorter vasoactive infusion duration in the intervention group** (95% CI, 14-42%;  $p < 0.01$ ). There were no significant trends observed in CICU LOS, or occurrence rate of CA or weaning failure.
- **The study concluded that the Etiometry system informed by IDO2 significantly decreased vasoactive infusions duration.** There was no discernible change in ICU LOS, CA rate, or weaning failure rate.

**Salvin, J. et al. (2017) The Impact of a Real-Time Physiologic Data Analytic Index on Length of Stay in Neonates Following Surgery for Congenital Heart Disease**

American Heart Association Abstract - 2017 November 11-15, Anaheim, CA

[https://www.ahajournals.org/doi/10.1161/circ.136.suppl\\_1.20603](https://www.ahajournals.org/doi/10.1161/circ.136.suppl_1.20603)

**STUDY LIMITATIONS:**

- Further analysis is ongoing to risk adjust the entire cohort and explore the impact of IDO2 on clinical decision making.

- Multi-center, retrospective cohort analysis of 673 patients admitted to the CICU after cardiac surgery evaluated the impact of implementing the Inadequate Oxygen Delivery Index (IDO2)
- 342 patients admitted pre-IDO2 Index implementation, and 331 patients admitted post-IDO2 Index implementation.
- **The introduction of the patient specific, real-time time physiologic index, IDO2, resulted in a significant (25%) reduction in ICU LOS of 0.75 (p=0.01).**
- In one center, when risk adjustment based on STAT score was included in the analysis, a relative reduction of 36% was observed.
- The reduction in LOS and possible reduction in costs are encouraging for determining the economic return on investment for such indices.

**Gaies, M. et al. (2023) Methods to Enhance Causal Inference for Assessing Impact of Clinical Informatics Platform Implementation**

Circulation: Cardiovascular Qual Outcomes. 2023 Feb;16(2):e009277. doi:10.1161/CIRCOUTCOMES.122.009277. Epub 2023 Feb 2. PMID: 36727516.

<https://www.ahajournals.org/doi/10.1161/CIRCOUTCOMES.122.009277>

**STUDY LIMITATIONS:**

- Unrecognized changes could have occurred in the CICU that led to improvement even without the T3 software implementation

- Retrospective comparative analysis of outcomes in a pediatric cardiac ICU, pre- and post-implementation of T3 against a multi-center control group.
- Compared 1,436 patients in the pre- and 779 in the post-implementation eras at a CICU to 19,854 (pre) and 14,160 (post) at control hospitals.
- Post implementation, the ICU incorporated a review of Etiometry for each patient during rounds to better assess the patient status based on the data, and create a data-informed care plan moving forward.
- **Relative reductions were observed in the CICU post-implementation for medical cardiac arrest (-14%) rates, unplanned ICU readmission rates (-41%), and postoperative CICU length of stay (-18%).**
- These improvements were significantly greater than changes at control hospitals (p<0.05 for all Difference-In-Difference interaction terms).

# VALIDATION

## Technology Validation

### Holman, H. et al (2024) Validation of the inadequate delivery of oxygen index in an adult cardiovascular intensive care unit

JTCVS Open. Volume 22, December 2024, Pages 354-361

<https://www.sciencedirect.com/science/article/pii/S2666273624002547>

#### STUDY LIMITATIONS:

- Single-center study
- Further investigation of IDO2 detection and clinical endpoints is needed.

- The study hypothesized that the IDO2 Index could predict impaired delivery of oxygen (IDO2) with comparable discrimination to invasive mixed venous oxygen saturation (SvO2) measurement.
- A total of 230 patients not on mechanical circulatory support (MCS) managed with a pulmonary artery catheter (PAC) were identified from 1012 patients admitted to a single cardiovascular intensive care unit (CVICU).
- 54 patients were used to train the model, which was then validated in 176 patients.
- A total of 1047 laboratory-validated SvO2 values were collected for the validation group. The area under the ROC curve for the IDO2 index was 0.89 (95% confidence interval, 0.87-0.91) with the full data set. When blinded to all PAC and SvO2 sources, the AUC was 0.78 (95% confidence interval, 0.75-0.81).
- **The study concluded that the IDO2 index is capable of detecting SvO2  $\leq$ 50% with good discriminatory function in non-MCS CVICU patients in a variety of monitoring situations**

### Viehl, L.T. et al (2025) Validation of a novel Bayesian predictive algorithm for detection of carbon dioxide retention using retrospective neonatal ICU data

Journal of Perinatology

Published online: July 23, 2025

<https://www.nature.com/articles/s41372-025-02369-z>

#### STUDY LIMITATIONS:

- Further testing and validation is needed.

- Respiratory failure is one of the most common diagnoses in the NICU and results in impaired gas exchange. While O2 saturation can be monitored non-invasively via pulse oximeter, CO2 can only be measured via blood gas (painful, intermittent) or transcutaneous CO2 monitoring (skin integrity, unpredictable performance).
- A retrospective study from two level IV NICUs validated the Inadequate Ventilation of Carbon Dioxide (IVCO2) index algorithm within the Etiometry platform against PaCO2 on gold standard blood gas analysis, and the risk of elevated PaCO2 scaled with a rising IVCO2 index.
- IVCO2 indices were calculated at 2 thresholds for all data and validated against clinical blood gas samples electronically timestamped at collection. For each blood gas time point, a matching IVCO2\_50 and IVCO2\_60 index was calculated as the mean value of all indices in the 30 min preceding the sample.
- Among 180 neonates included, 1092 arterial blood gas measurements were analyzed. **IVCO2\_50 and IVCO2\_60 demonstrated excellent discriminatory performance (AUC 0.87, 95% CI 0.85-0.89 and AUC 0.90, 95% CI 0.68-0.93, respectively).**
- The risk of elevated PaCO2 scaled linearly with increasing index quartiles. Minimum scores (<1) showed >6-fold reduction in hypercapnia risk, while maximum scores (>99) demonstrated >3-fold reduction in normocapnia risk.
- **The study concluded that IVCO2 index accurately predicts CO2 retention in neonates, offering potential for early detection of ventilation inadequacy without additional invasive monitoring.**

**Asfari, A. et al. (2023) A Near Real-Time Risk Analytics Algorithm Predicts Elevated Lactate Levels in Pediatric Cardiac Critical Care Patients**

Crit Care Explor. 2023 Dec 1;5(12):e1013.

[https://journals.lww.com/ccejournal/fulltext/2023/12000/a\\_near\\_real\\_time\\_risk\\_analytics\\_algorithm\\_predicts.3.aspx](https://journals.lww.com/ccejournal/fulltext/2023/12000/a_near_real_time_risk_analytics_algorithm_predicts.3.aspx)

**STUDY LIMITATIONS:**

- Single-center study
- Retrospective studies are required to analyze the effect of this index on clinical decision-making and outcomes.

- Postoperative pediatric congenital heart patients are predisposed to develop low-cardiac output syndrome. Serum lactate (lactic acid [LA]) is a well-defined marker of inadequate systemic oxygen delivery.
- Retrospective observational study in 10 tertiary CICUs in the United States and Pakistan was performed to validate a hyperlactatemia (HLA) index using T3 platform data (Etiometry, Boston, MA).
- A total of 58,168 LA measurements were obtained from 3,496 patients included in a validation dataset.
- HLA was defined as LA level greater than 4 mmol/L.
- The HLA index predicted HLA with high sensitivity and specificity (area under the curve 0.95). As the index value increased, the likelihood of having higher LA increased ( $p < 0.01$ ).
- **These results validate that this novel index can provide a noninvasive prediction of elevated LA.**

**Teele, S.A. et al. (2025) Investigation of a Novel Noninvasive Risk Analytics Algorithm With Laboratory Central Venous Oxygen Saturation Measurements in Critically Ill Pediatric Patients**

Crit Care Explor. January 2025 • Volume 6 • Number 1

[https://journals.lww.com/ccejournal/fulltext/2025/01000/investigation\\_of\\_a\\_novel\\_noninvasive\\_risk.10.aspx](https://journals.lww.com/ccejournal/fulltext/2025/01000/investigation_of_a_novel_noninvasive_risk.10.aspx)

**STUDY LIMITATIONS:**

- Retrospective study.
- IDO2 should not be used in isolation to assess the clinical status of a patient.
- Future studies should be aimed at the association of IDO2 with clinical outcomes and the impact of active integration of predictive analytics into patient management.

- A retrospective multicenter cohort study was conducted using data temporally independent from the design and development phase of the IDO2 index.
- A total of 20,424 Svo2 measurements from 3,018 critically ill neonates, infants, and children were retrospectively analyzed. Collected data included vital signs, ventilator data, laboratory data, and demographics.
- The ability of the IDO2 index to predict Svo2 below a preselected threshold (30%, 40%, or 50%) was evaluated for discriminatory power, range utilization, and robustness.
- Area under the receiver operating characteristic curve (AUC) was calculated for each index threshold. Datasets with greater amounts of available data had larger AUC scores. This was observed across each configuration.
- For the majority of thresholds, Svo2 values were observed to be significantly lower as the IDO2 index increased.
- **The study concluded that the IDO2 index may inform decision-making in pediatric cardiac critical care settings by providing a continuous, noninvasive assessment of oxygen delivery relative to oxygen demand in a specific patient.**
- **Leveraging predictive analytics to guide timely patient care, including support for escalation or de-escalation of treatments, may improve care delivery for patients and clinicians.**

## Etiometry vs. EHR

### Lowry, A. et al (2022) Acute vital signs changes are underrepresented by a conventional electronic health record when compared with automatically acquired data in a single-center tertiary pediatric cardiac intensive care unit

J Am Med Inform Assoc. 2022 Jun 14;29(7):1183-1190.

<https://academic.oup.com/jamia/article-abstract/29/7/1183/6550369?redirectedFrom=fulltext>

#### STUDY LIMITATIONS:

- Single-center study

- A retrospective observational study evaluated the fidelity with which the patient's clinical state is represented by the electronic health record (EHR) flow sheet vital signs data, compared to a commercially available automated data aggregation platform in a pediatric cardiac intensive care unit (CICU).
- Automated data captured for 72 h after admission were analyzed for significant HR SBP, RR, and SpO2 deviations from baseline (events). Missed events were identified when the EHR failed to reflect the events reflected in the automated platform.
- Analysis of 132,054,622 data entries, including 264,966 (0.2%) EHR entries and 131,789,656 (99.8%) automated entries, identified 15,839 HR events, 5,851 SBP events, 9,648 RR events, and 2,768 SpO2 events lasting 3-60 min; **these events were missing in the EHR 48%, 58%, 50%, and 54% of the time, respectively.**
- Subanalysis identified 329 physiologically implausible events (eg, likely operator or device error), of which 104 (32%) were nonetheless documented in the EHR.
- **The study concluded that EHR vital sign documentation was incomplete compared to an automated data aggregation platform, and therefore, enrichment of the EHR with automated data aggregation capabilities may improve representation of patient condition.**

## Escalation & De-escalation

### High Risk Patient Identification

### Magallon, A.L. et al (2024) Pediatric Tele-Critical Care: Initial Experience with a Continuous Surveillance Model Aiming to Prevent Cardiac Arrest in Children with Critical Heart Disease

Telemedicine and e-Health Vol. 30, No. 8

[https://www.liebertpub.com/doi/10.1089/tmj.2024.0035?url\\_ver=Z39.88-2003&rft\\_id=ori%3Arid%3Aacrossref.org&rft\\_dat=crpub++0pubmed](https://www.liebertpub.com/doi/10.1089/tmj.2024.0035?url_ver=Z39.88-2003&rft_id=ori%3Arid%3Aacrossref.org&rft_dat=crpub++0pubmed)

#### STUDY LIMITATIONS:

- The retrospective and descriptive nature of this report precludes establishing a relationship between team's communications and patient outcomes.

- A retrospective, descriptive review of tele-critical care (TCC) activities.
- Virtual support was provided to bedside teams from a TCC unit in a pediatric cardiac intensive care unit (CICU) and focused on early detection of concerning trends (CT) and avoidance of Cardiac Arrest (CA).
- Virtual surveillance workflows included a review of remote monitoring, video feed from patient room cameras, medical records, and artificial intelligence tools.
- 18,171 TCC activities were conducted, including 2,678 non-critical communications (CCs) and 248 CCs.
- **Over time, there was a significant increase in the proportion of CCs related with CT (p = 0.002), respiratory concerns (<0.001), and abnormalities in cardiac rhythm (p = 0.04).**
- Among a sample of 244 CCs, subsequent interventions by bedside teams resulted in adjustment of medical treatment (127), respiratory support (68), surgery or intervention (19), cardiac rhythm

**Dewan, M. et al. (2022) Low Inadequate Oxygen Delivery Index is Associated with Decreased Cardiac Arrest Risk in High-Risk Pediatric ICU Patients**

Crit Care Explor. 2022 Jan 5;4(1):e0600.

[https://journals.lww.com/ccejournal/fulltext/2022/01000/low\\_inadequate\\_oxygen\\_delivery\\_index\\_is\\_associated.5.aspx](https://journals.lww.com/ccejournal/fulltext/2022/01000/low_inadequate_oxygen_delivery_index_is_associated.5.aspx)

**STUDY LIMITATIONS:**

- The IDO2 was not clinically in use at the time of this study, and therefore, some patients were missing values to allow for a calculation of IDO2.
- Patients may have not been identified a watchers due to a variety of factors including admission or deterioration between bid huddles, poor communication of team during huddle to list accurate patient risk status, or because the deterioration was unexpected and, therefore, not predicted.

- Prospective observational cohort study in a single PICU.
- The study evaluated the Inadequate Oxygen Delivery Index (IDO2) to identify patients labeled as high risk by clinician concern who will not experience a cardiac arrest.
- 3,087 patients were monitored over 24,505 12-hour periods.
- 4,017 were watcher periods-12-hour period following watcher determination to watch for clinical deterioration.
- Overall, there were 224 clinical deterioration events of which 21% (n = 48) were cardiopulmonary resuscitation (CPR) events.
- Using clinical concern alone, the number needed to evaluate for CPR events was 167 watcher periods for each single CPR event and 43 watcher periods for each clinical deterioration event. With the addition of a mean IDO2 less than 5, the number needed to evaluate decreased to 125 and 38, respectively, with no change in the prediction of CPR events.
- The researchers concluded that the use of physiologic monitor data can be applied to clinician-activated situation awareness systems to decrease the number needed to alert and improve system efficiency.

**Dewan, M. et al. (2019) Validation of Etiometry T3 Inadequate Oxygen Delivery Algorithm to Pediatric Cardiac Arrest - LWW**

SCCM Abstract - 2019

February 17-19, San Diego, CA

[https://journals.lww.com/ccmjournal/Citation/2020/01001/1536\\_VALIDATION\\_OF\\_ETIOMETRY\\_T3\\_INADEQUATE\\_OXYGEN.1490.aspx](https://journals.lww.com/ccmjournal/Citation/2020/01001/1536_VALIDATION_OF_ETIOMETRY_T3_INADEQUATE_OXYGEN.1490.aspx)

**STUDY LIMITATIONS:**

- Single-center study
- Multicenter testing is necessary to validate these findings in a large more generalized population.

- The FDA cleared Inadequate Oxygen Delivery Index (IDO2), derived from multiple vital signs and laboratory values, is indicative of the likelihood that a patient is experiencing shock.
- A prospective case control study of 609 patients evaluated the use of IDO2 to predict in-hospital cardiac arrest (CA) in a general pediatric ICU.
- There were 28 cardiac arrests during this period of which 7 had captured data.
- The investigators found the IDO2 to be reliable in predicting in-hospital CA, most reliably at 2-hours prior to a CA with a 30-minute lag interval.

**Futterman, C. et al (2019) Inadequate oxygen delivery index dose is associated with cardiac arrest risk in neonates following cardiopulmonary bypass surgery**

Resuscitation. 2019 Jul 17;142:74-80.

[https://www.resuscitationjournal.com/article/S0300-9572\(19\)30522-2/abstract](https://www.resuscitationjournal.com/article/S0300-9572(19)30522-2/abstract)

**STUDY LIMITATIONS:**

- The retrospective nature of the data limits the ability to track real time management decisions, changes in support, and other confounding factors. While we can hypothesize that these CA events were preventable, a future interventional clinical trial would be needed to test such hypothesis.

- Multicenter retrospective cohort study in 3 US pediatric cardiac intensive units evaluated the Inadequate oxygen delivery (IDO2) index dose as a predictor of cardiac arrest (CA) in neonates following congenital heart surgery.
- 897 patients were monitored during the study period, 601 met the inclusion criteria included in study, 29 patients had CA (33 events) and 572 patients were control events.
- IDO2 dose was computed over a 120-min window up to 30 min prior to the CA and control events. Values were blinded to bedside clinicians.
- **The study found that In neonates post-CPB surgery, higher IDO2 index over a 120-min monitoring period is associated with increased risk of cardiac arrest, even when censoring data 10, 20 or 30 min prior to the CA event.**

### Zaccagni, H. et al (2021) Track and Trigger System Based on Patient Analytics for Cardiac Arrest Risk Identification

American Heart Association Abstract - 2021 November 13-15 - Virtual Scientific Sessions

[https://www.ahajournals.org/doi/10.1161/circ.144.suppl\\_1.11370](https://www.ahajournals.org/doi/10.1161/circ.144.suppl_1.11370)

#### STUDY LIMITATIONS:

- Further validation of these data in other cohorts and prospective application of the tool is warranted.

- A quality improvement project of Cardiac Arrest Prevention (CAP) used risk analytics algorithm of patient physiology that computes risk indices for various physiologic variables.
- Risk indices examined in this study include IDO2 (likelihood of SvO2 < 40%), HLA (likelihood of lactate > 4 mmol/L), and IVC02 (likelihood of PaCO2 > 50 mmHg).
- Various criteria using these risk indices were retrospectively evaluated for categorizing risk status. Once criteria were met a 12-hour “watcher period” was established after a 1-hour assumed response period. CAP status was assigned on a daily basis.
- 665 encounters for 484 patients were included.
- **There were a total of 29 CA, of which 11 (38%) were captured by CAP.**
- **Augmenting the CAP protocol with Risk Analytics was able to capture up to 62% of CA events.**
- **The study suggests that automated risk analytics can offer patient-specific tools to identify risk periods in real time.**

## Vasoactive Weaning

### Goldsmith, M. et al (2021) Use of a Predictive Analytic Algorithm to Inform Vasoactive Medication Weaning in Patients Following Cardiac Surgery

Critical Care Explorations 3(11):p e0563, November 2021.

[https://journals.lww.com/ccejournal/fulltext/2021/11000/use\\_of\\_a\\_risk\\_analytic\\_algorithm\\_to\\_inform\\_weaning.3.aspx](https://journals.lww.com/ccejournal/fulltext/2021/11000/use_of_a_risk_analytic_algorithm_to_inform_weaning.3.aspx)

#### STUDY LIMITATIONS:

- The findings in this study are limited by retrospective design, lack of several important patient characteristic details, and did not capture practitioner decision making in stopping and starting inotropic agents

- Multicenter retrospective cohort study of patients following cardiac surgery, who required vasoactive infusions for more than 6 hours in the postoperative period.
- The study assessed whether inadequate delivery of oxygen index was associated with failure to wean off vasoactive infusions.
- The study identified postoperative patients who successfully weaned off initial vasoactive infusions (n = 2,645) versus those who failed vasoactive wean (n = 516).
- Inadequate delivery of oxygen index for final 6 hours of vasoactive wean was captured.
- **During the de-escalation phase of postoperative cardiac ICU management, inadequate delivery of oxygen index, was associated with failure to wean off vasoactive infusions.**

## RBC Transfusion Response

### Said, A. et al (2018) Transfusion Response Prediction by Integrated Measure of Oxygen Delivery (IDO2 Index)

Pediatric Critical Care Medicine 19(6S):p 123-124, June 2018.

[https://journals.lww.com/pccmjournal/fulltext/2018/06001/abstract\\_p\\_252\\_\\_transfusion\\_response\\_prediction\\_by.367.aspx](https://journals.lww.com/pccmjournal/fulltext/2018/06001/abstract_p_252__transfusion_response_prediction_by.367.aspx)

#### STUDY LIMITATIONS:

- Single-center study and relatively small sample size.

- Prospective/Retrospective study: 3 PICU groups receiving blood; a prospective group and 2 retrospective groups with cardiac output monitoring during transfusion.
- 98 transfusion events met the study criteria, 71 included CO monitoring a required parameter for study inclusion.
- The study found that RBC transfusions have a variable impact on delivery of O<sub>2</sub>, and that impact is dependent on pre-transfusion status of O<sub>2</sub> delivery, an elevated IDO2 indicates a post-transfusion benefit
- **The study suggests that assessment of pre-transfusion O<sub>2</sub> delivery may improve transfusion decision making. The researchers observed that an indication of impaired O<sub>2</sub> delivery pre-transfusion, an elevated IDO2 Index, indicated a post-transfusion benefit.**

## Extubation Readiness

### Hames, D. et al (2025) Extubation Failure in Neonates Following Congenital Cardiac Surgery: Multicenter Retrospective Cohort, 2017–2020

Pediatric Critical Care Medicine, February 10, 2025.

[https://journals.lww.com/pccmjournal/abstract/9900/extubation\\_failure\\_in\\_neonates\\_following.435.aspx](https://journals.lww.com/pccmjournal/abstract/9900/extubation_failure_in_neonates_following.435.aspx)

#### STUDY LIMITATIONS:

- Prospective studies incorporating these thresholds in ventilator liberation are required.

- Extubation failure (EF) in neonates recovering from congenital cardiac surgery is associated with morbidity and mortality.
- Multicenter retrospective cohort study in 8 international pediatric cardiac ICUs, aimed to evaluate the association of two physiologic risk analytics algorithms evaluating the probability of inadequate delivery of oxygen index (IDO2) and inadequate ventilation of carbon dioxide index (IVCO2) with EF in neonates receiving mechanical ventilation (MV) after cardiac surgery.
- Data from 736 neonates were analyzed with 102 (13.9%) having EF (defined as reintubation within 48 hr of extubation).
- In multivariable analysis of patients with both pre-extubation IDO2 and IVCO2 data, **single ventricle anatomy (OR, 2.50 [95% CI, 1.27–4.92]) and high IDO2 (≥ 25) or high IVCO2 (≥ 50) in the 2 hours preceding extubation (OR, 1.77 [95% CI, 1.01–3.12]) were associated with greater odds of EF.**
- **The study concluded that the IDO2 and IVCO2 algorithms may be useful in assessing risk of EF in post-cardiac surgery neonates receiving at least 48 hours of MV.**

### Hames, D. et al (2022) Associations With Extubation Failure and Predictive Value of Risk Analytics Algorithms With Extubation Readiness Tests Following Congenital Cardiac Surgery

Pediatr Crit Care Med. 2022 Apr 1;23(4):e208-e218.

[https://journals.lww.com/pccmjournal/abstract/2022/04000/associations\\_with\\_extubation\\_failure\\_and.20.aspx](https://journals.lww.com/pccmjournal/abstract/2022/04000/associations_with_extubation_failure_and.20.aspx)

#### STUDY LIMITATIONS:

- IDO2 and IVCO2 provide unique cardiorespiratory monitoring parameters during ERTs but require further investigation before being used in clinical evaluation for extubation failure.

- Retrospective cohort study of children receiving MV for more than 48 hours following cardiac surgery.
- The study aimed to identify factors associated with extubation failure in children following cardiac surgery, and assess the performance of two risk analytics algorithms for patients undergoing an ERT.
- 650 encounters were analyzed with 49 occurrences (8%) of reintubation. Extubation failure occurred most frequently within 6 hours of extubation.
- The study found that the institutional ERT had low sensitivity to identify patients at risk for reintubation (23.8%; 95% CI, 9.7–47.6%).
- **The addition of the inadequate delivery of oxygen (IDO2) index to the ERT increased the sensitivity by 19.0% (95% CI, -2.5 to 40.7%; p = 0.05), but the sensitivity remained low and the accuracy of the test dropped by 8.9% (95% CI, 4.7–13.1%; p < 0.01).**

## Sepsis Management

### Roy, k. et al (2022) Inadequate Oxygen Delivery Dose and Major Adverse Events in Critically Ill Children With Sepsis

Am J Crit Care. 2022 May 1;31(3):220-228.

<https://aacnjournals.org/ajconline/article/31/3/220/31745/Inadequate-Oxygen-Delivery-Dose-and-Major-Adverse>

#### STUDY LIMITATIONS:

- Single-center study

- The study evaluated the relationship between IDO2 dose and major adverse events, illness severity metrics, and outcomes among critically ill children with sepsis.
- Clinical and IDO2 data were retrospectively collected from the records of 102 critically ill children with sepsis, without preexisting cardiac dysfunction.
- **Inadequate oxygen delivery doses were significantly higher in patients who experienced major adverse events (n = 13) than in those who did not (n = 89).**
- Patients with an IDO2 dose at 0 to 12 hours at or above the 80th percentile had the highest odds of a major adverse event (odds ratio, 23.6; 95% CI, 5.6-99.4).
- Significant correlations were observed between IDO2 dose at 0 to 12 hours and day 2 maximum vasoactive inotropic score ( $p = 0.27$ ,  $P = .006$ ), day 1 Pediatric Logistic Organ Dysfunction (PELOD-2) score ( $p = 0.41$ ,  $P < .001$ ), day 2 PELOD-2 score ( $p = 0.44$ ,  $P < .001$ ), intensive care unit length of stay ( $p = 0.35$ ,  $P < .001$ ), days receiving invasive ventilation ( $p = 0.42$ ,  $P < .001$ ), and age ( $p = -0.47$ ,  $P < .001$ ).
- The researchers concluded that routine IDO2 monitoring may identify critically ill children with sepsis who are at the highest risk of adverse events and poor outcomes.

## Acute Kidney Injury

### Kilcoyne, M.F. et al (2024) Association Between the Inadequate Delivery of Oxygen (IDO2) Index and Acute Kidney

Southern Thoracic Surgical Association  
Abstract - 2024  
November 7-10, Austin, TX

#### STUDY LIMITATIONS:

- Single-center study
- Future research is warranted to explore the clinical utility of IDO2 exposure in predicting post-cardiac surgery

- Retrospective study that assessed whether there is a significant correlation between IDO2 index (SVO2 <50%) and post-cardiac surgery acute kidney injury (AKI).
- During the study period, 1,357 patients underwent cardiac surgery and 301 patients (22.2%) met the inclusion criteria. Of these 301 patients, 34 patients (11.3%) experienced an AKI and the remaining 267 patients were designated as the control group.
- The median age between the control (66.2 years old) and AKI group (65.9 years old) were similar between groups ( $p = 0.43$ ). The majority of the control (73.0%) and AKI group (74.0%) were male ( $p = 0.92$ ).
- **Median IDO2 exposure was significantly higher in the AKI group (21.92 [IQR: 10.85 – 35.72]) compared to the control group (9.32 [IQR: 2.91 – 23.40]) ( $p < 0.01$ ).**
- IDO2 exposure was compared between AKI patients and those without a postoperative AKI using the Mann-Whitney U test. Binary logistic regression was used to calculate risk of AKI based on predetermined IDO2 exposure ranges.
- **The study concluded that the IDO2 exposure within the first 24 hours after cardiac surgery was significantly associated with an increased risk of AKI during the postoperative period.**

## Pre-ECMO Markers

### Rabinowitz, E.J. et al (2022) Pre-ECMO markers of impaired oxygen delivery and neurologic outcomes

Pediatric Cardiac Intensive Care Society  
Abstract - 2022  
December 15-18, Miami, FL

#### STUDY LIMITATIONS:

- Single-center study and relatively small sample size.
- Future multi-institutional studies are required to validate these findings and evaluate the impact of ECMO initiation decision support tools that incorporate markers of impaired oxygen delivery on patients' short and long-term neurologic outcomes.

- The clinical decision to provide extracorporeal membrane oxygenation (ECMO) is challenging unless patients are in physiological extremis. Current ECMO prognostication scores are limited to mortality as the primary outcome, reliance on immediate pre-ECMO variables not taking into account evolving patient trajectories and have not been validated for patient level decision making.
- The inadequate oxygen delivery index (IDO2) is a multi-variate risk analytic algorithm combining physiologic and laboratory parameters from bedside monitors and the electronic medical record into a single near real-time probability of central venous saturations being below <40%, representing the probability of inadequate oxygen delivery.
- The single center study included 47 infants and evaluated the association between pre-ECMO IDO2 variables with adverse post-ECMO neurologic outcomes in infants supported on ECMO.
- Each unit increase in IDO2 dose at 2 hours pre-ECMO, and with each minute over IDO2 threshold of 75%, increased odds of mortality by 3% (p=0.02) and 5% (p=0.01) respectively. These odds were more than 6-fold higher in post-arrest patients.
- With each unit increased IDO2 dose at 6 hours prior to ECMO initiation, odds of abnormal head CT increased by 23% (p=0.01) and odds of asymmetric EEG background increased by 12% (p=0.03).
- With each minute spent over 25 and 50% thresholds, odds of asymmetric EEG background increased by 21% (p=0.01) and 50% (p=0.03) respectively.
- Multivariate logistic regression model of time above the IDO2 thresholds at the studied time points identified patients with combined outcome of mortality or FSS >10 with area under receiver operator curve of 0.81 (95% confidence interval 0.7-0.93, p=0.0002).
- **This study showed that duration and depth of pre-ECMO inadequate oxygen delivery, measured by IDO2, is associated with worse functional outcomes, neuroimaging abnormalities and death. Incorporation of the evolving patients' trajectories and degree of impaired oxygen delivery could be informative in the decision making to initiate ECMO.**

## Goal-Directed Therapy

### Lobbestael, A. et al (2024) Association of goal-directed therapy adherence and decreased ICU length of stay

American Association for Thoracic Surgery  
Abstract - 2024 April 17-30. Toronto, Canada

#### STUDY LIMITATIONS:

- Single-center study

- Goal-directed therapy (GDT) in post-operative patients decreases ICU length of stay (LOS). The inadequate delivery of oxygen index (IDO2) is a validated machine learning algorithm that predicts poor oxygen delivery, defined as SVO2 <50%.
- The study evaluated a GDT pathway that uses basic available data combined with IDO2 and assessed its association with ICU LOS and ICU mortality in post cardiac surgical patients at a single high-volume center.
- A total of 397 patients met inclusion criteria. For each patient, GDT compliance was quantified as the percentage of time satisfying 4 GDT guidelines: mean arterial pressure (MAP) > 60 mmHg, mixed venous oxygen (SvO2) > 50%, continuous cardiac index (CCI) > 2L/min/m2 and temperature > 36.5°C. Using median GDT compliance, patients were separated into low and high compliance groups. ICU LOS and mortality were compared between groups. This process was repeated using only 2 GDT guidelines (MAP and temperature) and again for each model with the addition of IDO2.
- **When using all 4 parameters, the median ICU LOS for high vs low compliance was 2.70 (1.93-4.23) vs 3.56 (2.27-5.49) days (p<0.0001) without IDO2 and 2.62 (1.85-4.21) vs 3.63 (2.33-5.49) days (p<0.0001) with the addition of IDO2.**
- **For the 2-parameter model, the median ICU LOS for high vs low compliance was 2.83 (1.94-4.49) vs 3.39 (2.20-5.04) days (p<0.01) without IDO2 and 2.71 (1.94-4.23) vs 3.56 (2.23-5.50) days (p<0.0001) with the addition of IDO2.**
- Differences in mortality was not significant between any groups.
- **The study concluded that goal-directed therapy models using as little as two parameters of MAP and Temperature with the addition of IDO2 can reach near-equivalent predictive value for ICU LOS in post-operative cardiac surgery patients as the four GDT model.**

# NURSING WORKFLOW

## Lowry, A.W. et al (2020) Please Step Away From the Computer: A Pilot Study To Improve Efficiency and Reduce Nursing Workload in the Cardiac Intensive Care Unit Using an Automated Data Collection and Aggregation System

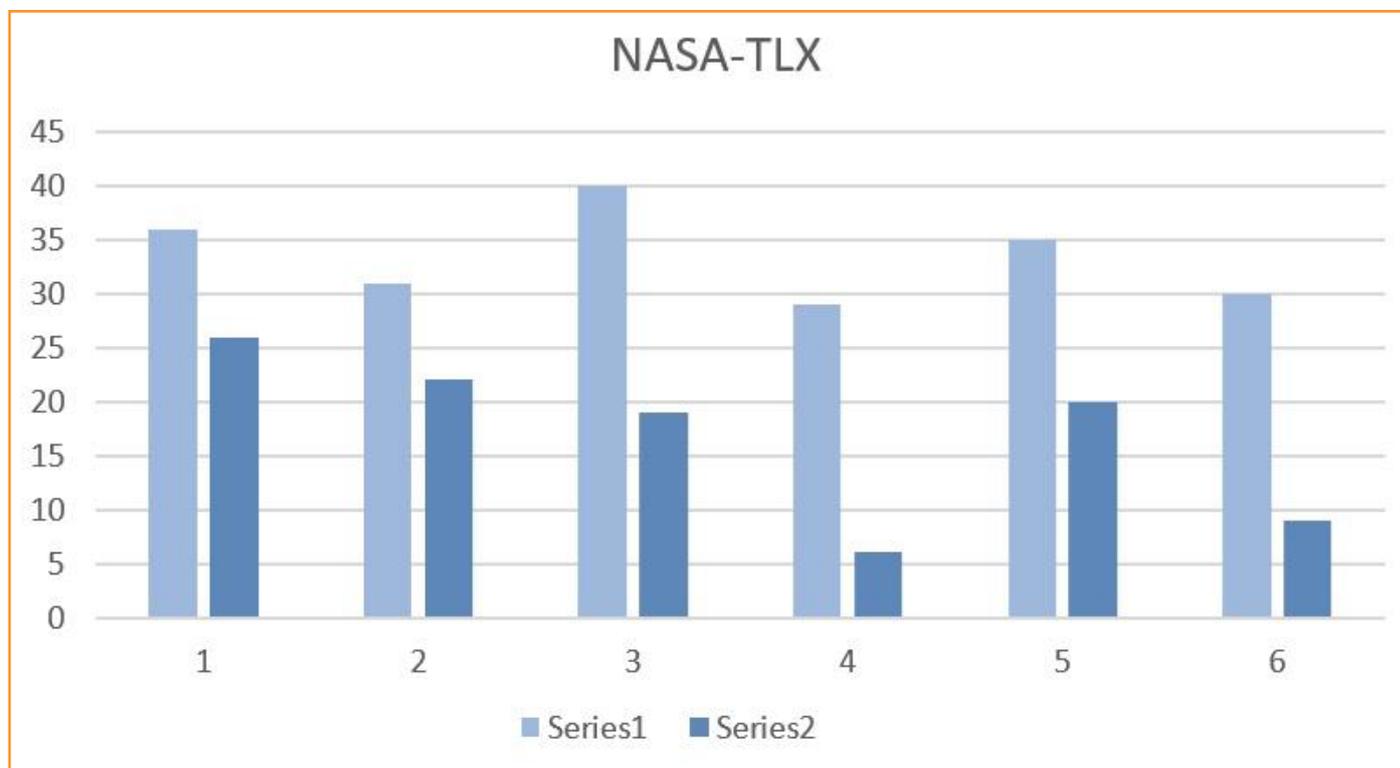
Pediatric Cardiac Intensive Care Society  
Abstract - 2020

December 9-11, Virtual Annual Meeting

### STUDY LIMITATIONS:

- Single-center study
- Given that provider workload has been directly associated with patient outcomes in the ICU, additional investigation into workload reduction strategies is warranted.

- High nurse workload in the intensive care unit (ICU) may lead to a greater number of adverse events, such as ventilator associated pneumonia, hospital-acquired infection, adverse medication events, and falls. Ultimately, this may lead to lower quality, longer stays, increased cost, or increase mortality.
- The study assessed nursing workload and satisfaction with handoff and rounds through the use of questionnaires completed immediately after rounds. This was performed before and after implementation of the Etiometry T3 Platform, which is an automated data aggregation and display platform with predictive analytics capabilities.
- Providers were all trained on the system prior to installation (physicians, respiratory therapists, & nurses).
- During bedside rounds prior to implementation, nurses recite a summary of vital signs for the preceding 12 hours, read from a data sheet hand written by the nurse prior to rounds. After implementation, nurses provided a conversational summary of the patient's recent state, using the aggregated data on the dedicated beside T3 display in each room.
- During the pre- and post-implementation period, nurses were asked to complete a questionnaire on a tablet computer immediately after rounds. Nursing perception of workload was assessed using the 6-question validated NASA Task Load Index survey (NASA-TLX), and general satisfaction with the process was measured through 23 additional user experience questions.
- **The NASA-TLX workload survey revealed significant improvements in perceived workload across all domains after implementation of T3: mental workload, physical workload, time pressure, success in completing the task, overall workload, and frustration with process.**
- Figure 1 depicts averages of all survey responses for each question, demonstrating that **workload before implementation (Series 1) is higher than perceived workload after implementation (Series 2). The satisfaction survey revealed increased user satisfaction with the process after implementing T3, with all 23 questions reflecting a positive impact and 18 of 23 with statistically significant differences in workflow improvement.**
- **The study concluded that perceived workload and provider satisfaction were both meaningfully improved by implementation of an automated data aggregation and analytics platform.**



**Figure 1.** NASA-TLX Survey Results Before (Series 1) and After (Series 2) Implementation of T3 Platform

**Question 1:**

How much mental and perceptual activity was required? (Easy/Simple vs Demanding/Complex)

**Question 2:**

How much physical activity was required? (Easy/Simple vs Demanding/Complex)

**Question 3:**

How much time pressure did you feel due to the pace at which the tasks or task elements occurred? (No time pressure/ vs Pressured)

**Question 4:**

How successful were you in performing the task? (Very successful/Satisfied vs Very frustrated/ Unsuccessful)

**Question 5:**

How hard did you have to work (mentally and physically) to accomplish your level of performance? (Demanding/Complex vs Easy/Simple)

**Question 6:**

How frustrated, discouraged, or annoyed did you feel while completing this process? (No frustration/Satisfied vs Frustrated/Very annoyed)