Paediatric Early Warning Scores as a Robust Signal for Unanticipated Admission to the Paediatric Intensive Care Unit from Surgery

Bridget Dolan[1], Ian Dawkins[2], Dr Brendan O'Hare[2].

[1]School of Medicine, Trinity College, University of Dublin, Ireland
[2]Our Lady's Children's Hospital Crumlin, Ireland

Abstract

To evaluate the link of a Paediatric Early Warning System (PEWS) Score with an unplanned transfer to Paediatric Intensive Care unit (PICU) in hospitalized ward patients following surgery. PEWS scores have not been evaluated (to the best of our knowledge) in a distinct cohort of ward-based patients requiring unplanned admission to PICU after having undergone surgery. A retrospective audit of PICU admissions over a 12-month time period from January-December 2017 was performed. Clinical information was collected from Philips IntelliSpace Critical Care and Anesthesia (ICCA) System, Theatre Management System (TMS) and Paediatric Intensive Care Audit Network (PICAnet). Tertiary/Quaternary level dedicated children's hospital in Ireland, [Our Lady's Children's Hospital Crumlin (OLCHC)]. In 2017 OLCHC had 1051 PICU admissions. 455 were selected that had an absolute time difference between PICU admission and theatre exit of 240 minutes or less. Of these 455 patients, 34 were coded as having unplanned transfers to PICU from a ward post operating theatre. There is no correlation between elevated PEWS scores and unplanned transfers to PICU following surgery. Our finding shows that 73.5% of patients have a PEWS score equal to 3 or less. PEWS does not appear to provide an additional signal preoperatively for the need for an escalated level of care for paediatric patients following their surgery.

Introduction

Paediatric Early Warning Scores (PEWS) serve to notify health care professionals of the current status and deterioration of a child in order to promote a quick and efficient intervention to halt deterioration (Chapman et al, 2017). This system is based on the measurement of vital signs, a mainstay of patient evaluation.

Before PEWS was established for evaluating paediatric patients' status, clinicians used the patient's vitals to assess their level of care. Vitals include blood pressure, body temperature, pulse, and respiratory rate. Clinicians could incorporate the severity of these vitals into their decision-making plan, often referred to in newer works as usual care. Usual care relies on the physician's years of experience and education in order to make an accurate decision (Parshuram et al 2018). However,

vitals were often not discriminative enough, and the method of evaluation of vitals is constantly debated (Lockwood 2004), leading to the creation of new patient observations systems.

Limitations of Vital Signs

In order to achieve an accurate assessment of a patient, all vital signs must be measured consistently. However, a 2011 study performed in the UK showed that nurses may only evaluate certain parameters 50% of the time, thereby missing key vital signs that could alert medical staff of a potential serious adverse event. At this time, hospitals had yet to establish policies or guidelines on how to evaluate and document these vital signs. Thus, vital signs could be interpreted differently depending on which member of the medical staff evaluated the patient, leading to potential ambiguity surrounding the patient's condition. It was also found that nurses were delaying calls to rapid response teams for hours at a time or alerting the wrong medical team (Kyriacos, 2011).

These limitations led to the development of Early Warning Systems (EWS), by William and Wright in the UK. They created this system to include all the vital signs with ranges corresponding to levels of deterioration. This deterioration could be given a score, and thus was the first time that a physician could quantify the severity of a patient's condition. This system also created a course of action by determining which health care providers should be monitoring the patient at one particular time and how often they should be reevaluated (Kyriacos, 2014). By adding these parameters, the EWS eliminated any discrepancies in the evaluation of a patient's condition and produced efficient steps of intervention and action.

Scoring Systems in Other Contexts

Other scoring systems have evolved to help physicians determine if a patient is at risk of deterioration. For instance, in anaesthesia there is the *American Society of Anaesthesiologists Physical Classification System* (ASA Status). This is a global physical score that assesses patients' physical status before surgery, thereby assisting in postoperative planning decision-making, such as if a patient is admitted to a ward or an ICU. Similarly, in paediatric critical care medicine, the *Paediatric Index of Mortality* (PIM) scoring system has evolved to provide a risk adjusted mortality among children admitted to the PICU. It does not provide a score for an individual patient but allows comparisons between populations of different PICU to assist in the assessment of the quality of their practice (Straney et al, 2013).

Categories of PEWS

There are eighteen variations of PEWS, which are divided into scoring and trigger systems. Scoring systems apply a quantitative value to vital signs. These vital signs include respiratory rate, respiratory

effort, oxygen therapy, SpO2, heart rate, central capillary refill time, blood pressure, the alert, verbal, pain, unresponsive (AVPU)scale, and temperature. These values are adjusted depending on the age range of the patient. Trigger-based systems create a threshold value for the different vitals, but do not combine them into an overall score. Overall, score-based PEWS typically perform better at predicting deterioration (Chapman et al 2017).

Benefits of PEWS

In the events leading up to rapid deterioration or unexpected death in hospital, a child will often present with distinguishable features. A study in the UK discovered roughly 1 in 5 paediatric deaths in hospital are avoidable when these features are recognized and attended to promptly (Harnden et al 2009). This early identification is essential for quality medical care and appropriate allocation of medical staff and resources in hospital wards. PEWS is a more specific version of the EWS. It detects the level of deterioration based on the child's vitals, colouring and behaviour, and is used to assess how often the patient should be re-evaluated. Since the introduction of this system there have been improved outcomes in cardiopulmonary arrest and earlier intervention to reduce the likelihood of PICU transfers (Chapman et al, 2017). It also has an age-defined threshold that further increases the specificity of the PEWS. This includes 0-3 months, 4-11 months, 1-4 years, 5-11 years, and 12 years and over. It is currently still debated whether the *Irish Paediatric Early Warning System* created by the National Patient Safety Office PEWS scores have a major impact on child care.

Purpose of our study

The objective of this study is to evaluate the correlation of a PEWS score with an unplanned transfer to PICU in hospitalized ward patients following surgery. This study is pertinent because, to the best of our knowledge, PEWS has not been evaluated in this specific cohort alone before. PEWS scores have been utilized in various hospital wards but have not been previously evaluated in the paediatric pre-operative setting. Therefore, we propose to analyse the Our Lady's Children's Hospital Crumlin (OLCHC) PICU Clinical information system, Philips HealthCare IntelliSpace Critical Care and Anesthesia (ICCA) and Theatre Management System (TMS) from January to December 2017 to profile the PEWS scores of this group and explore the possibility that PEWS could provide some signal as to the requirement of escalated level of care for these patients following their surgery. Similarly to how ASA provides a signal during surgery and PIM3 provides a signal once in PICU, we want to evaluate if PEWS can predict an unexpected admission from theater to PICU.

We hypothesize that a PEWS score above 3 would correlate to a higher risk of clinical deterioration. This value was chosen based on the recent study *Evaluation of a Pediatric Early Warning Score*

Across Different Subspecialty Patients that documented that a PEWS score equal to 3 or less did not lead to a deterioration event (Gold et al., 2014). We define a clinical deterioration as the unplanned transfer to PICU following a transfer from the ward to the operating theatre. We hope that research in this field will lead to the greater awareness of the clinical utility (or lack thereof) of PEWS, provide anaesthesiologists with more clarity on the severity of their patients' status and ultimately reduce the number of unexpected PICU admissions. Could PEWS assist the anaesthesiologist when planning a perioperative course for a sick infant or child going to the operating theatre? Specifically, could it assist in forward planning and deciding which patients should return to the ward post-operatively and, more importantly, could it aid in assessing which patients attend ICU post-operatively, with immediate access to life supporting therapies that follows? Put simply, would pre-operatively measured PEWS decide for any given patient whether their post-operative care should be on the ward or in the ICU?

Methods

This was a retrospective audit over the 12-month time period from January – December 2017 utilising the PEWS scores of paediatric patients from transfers to PICU following surgery at OLCHC. This study was executed at OLCHC which had over 1,000 PICU admissions in the year 2017. This major tertiary care children's hospital follows the *National Clinical Guidelines of the Irish Paediatric Early Warning System,* which was recently updated in November 2016. PEWS scores were already being utilised in OLCHC over the period covered in the audit and therefore no additional training of nurses and other hospital staff was needed in its use. Data was collected via PICAnet, TMS and Philips ICCA at OLCHC during the year 2017. Patients who qualified for this study had an absolute time difference between PICAnet and TMS of 240 minutes or less.

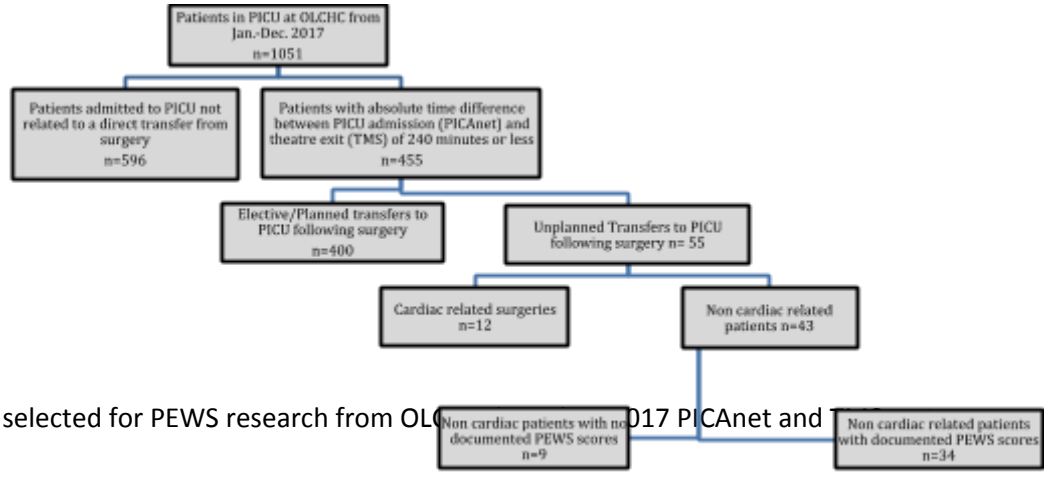

Figure 1: Patients selected for PEWS research from OLCHC 2017 PICAnet and TMS records.

Cardiac patients were excluded from our study because this cohort utilizes a cardiac -specific PEWS. This system makes allowances for cyanosed patients and those more susceptible to cardiac arrests (McLellan and Connor 2013).

In addition to PEWS scores, other factors were also documented in order to discover any possible secondary outcomes. This included the patient's age, time in hospital prior to surgery, if resuscitation was needed prior to surgery (including any necessary treatment to sustain life including fluids, commencing inotropes etc.). It also included the operation performed at surgery, a general diagnosis, the duration of general anaesthesia status, major interventions performed in PICU, PICU length of stay, and the specific reason why the patient was admitted to ICU.

Results

Of the 34 patients who qualified for this study, the average age was 4.7 years. There were slightly more males (58.8%, n=20) than females (41.2 % , n=14). The average length of stay in hospital prior to surgery was 119.2 hours. Only a small portion (38.2%, n=13) of our patients required resuscitation prior to transfer to theatre. The majority of patients experienced laparotomies, many of which were explorative or bowel-related. The average time under general anaesthesia equated to 2.7 hours, with an average assigned ASA status of 2.7 as well. A majority of our patients experienced a major adverse event within the first 24 hours of their admission to PICU, with 20.6% needing inotropes and 41.2% needing intubation. This included patients who remained intubated and ventilated following theatre and patients who required additional ventilation after extubation in theatre. Once in PICU, they stayed on average for 4.6 days (Table 1).

Patients' clinical status determines whether they receive High Dependency Unit (HDU) monitoring care or higher acuity PICU-level care. Often the severity of a patient's condition determines what level of care they will need, with PICU for the most severe and HDU for patients who do not require intubation or inotropes. This is demonstrated in Figure 2, alongside the severity of PEWS score and the number of patients in that category. It was found that 73.5% (n=25) of our patients had a PEWS score ≤ 3.

In our study we recorded the 4 highest PEWS leading up to a patient's surgery. Although 34 patients had documented PEWS scores leading up to their surgery, it was noted that 26.4% of these patients did not have 4 complete PEWS scores to assess.

Table 1: Demographics and Variables of Patients Included in the Study (n=34)	
Demographic	**Value**
Average Age (yrs)	4.7 (4.0,5.3)
Gender (no., %) Males Females	 20 (58.8%) 14 (41.2%)
Average Time in Hospital Prior to Surgery (hrs, CI)	119.2 (93.2, 145.3)
Procedures (no., %) Laparotomy Laparoscopic procedures Nephrology related Vascular related Orthopedics related ENT related MISC. (MRI, chest drain, biopsy, laser eye surgery)	 11 (32.4%) 6 (17.6%) 1 (2.9%) 2 (5.9% 3 (8.8%) 5 (14.7%) 6 (17.6 %)
Average Time under General Anaesthetic (hours, CI)	2.7 (2.5, 2.9)
Average ASA Status (score, CI)	2.7 (2.6, 2.8)
Average PICU Length of Stay (days, CI)	4.6 (4.1,5.1)
Intervention Need within the first 24hrs in PICU (no., %) Intubated Patients Inotropes given	 14 (41.2%) 7 (20.6%)
Resuscitation needed prior to Operating Theatre (no., %)	13 (38.2%)

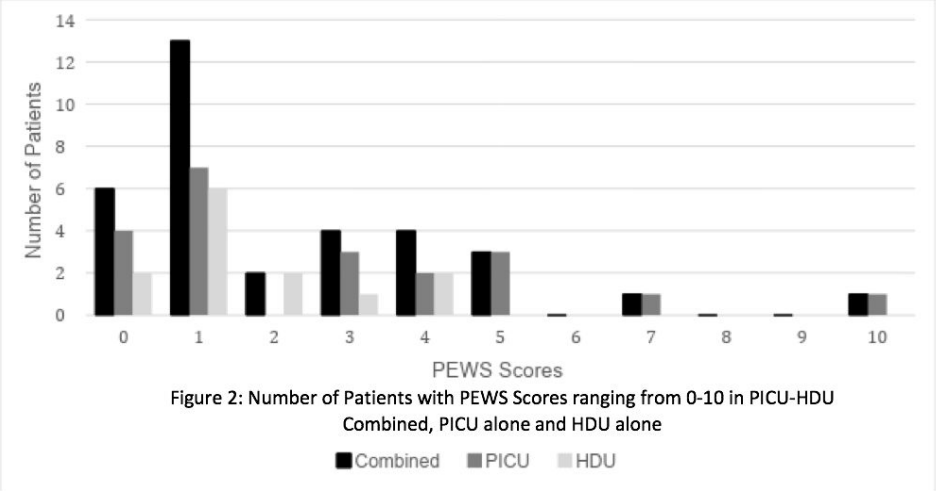

Figure 2: Number of Patients with PEWS Scores ranging from 0-10 in PICU-HDU Combined, PICU alone and HDU alone

Discussion

It was found that 73.5% (n=25) of our patients had a PEWS score ≤3, showing that PEWS do not provide a robust signal for unplanned admission to PICU for hospitalized patients who had undergone surgery. To the best of our knowledge this was the first time that PEWS scores have been examined in this distinct cohort of patients. This audit was performed in the hopes of providing anaesthesiologists and other members of the health care system a better means of predicting the level of care a patient may need and ultimately avoiding unplanned transfers to PICU.

There were no significant secondary outcomes from this study. The following parameters showed a correlation value of less than 1: Time in hospital prior to surgery, ASA status, time under general anaesthesia, PICU length of stay and age [Appendix 1, Figures 3-7]. Bedside PEWS scores were created in the hopes of eliminating deterioration events in hospitalized ward patients. We looked to exploit the PEWS scores to see if it offered another means of application, and in this case aid anaesthesiologists in their ability to predict the likelihood of transfer to PICU. However, based on our findings, PEWS scores do not offer this added ability.

Our findings are consistent with the recently published study titled *Effect of a Pediatric Early Warning System on All- cause Mortality in Hospitalized Pediatric Patients* (Parshuram et al, 2018). This 4 year long, 21 hospital, international study evaluated PEWS scores as a signal for deterioration events and mortality in paediatric ward patients. The all-cause mortality rate for bedside PEWS was 0.84 compared to a rate of 0.50 seen in usual care. Thus, it was found that PEWS did not provide an additional signal and that a physician's best judgement and usual care were sufficient in determining a patient's level of care. Our study differs because it adds the additional element of ward patients who required surgery.

Does this discredit PEWS as an evaluation tool? There are still many studies that do provide significant correlations with evaluated PEWS scores and unplanned transfer to PICU. In 2016, a paper titled *Validation of a Pediatric Early Warning Score in Hospitalized Pediatric Oncology and Hematopoietic Stem Cell Transplant Patients* evaluated over one hundred patients over a two-year timeline and proved that there was a high correlation with elevated PEWS and unplanned transfers to PICU (Agulnik et al, 2018). The difference between this study and our own is that there is a lack of surgical context, which is to be expected due to the specific patient population in our study. In addition, they denote their patients as being significantly at risk, meaning all patients were chronically ill and had been admitted to the wards for an extensive amount of time (as opposed to our study where patients had on average spent only 119.2 hours on the wards). This demonstrates that there is a need for PEWS; however, it is very context and patient specific. What is important to note is that this international study does not suggest that PEWS scores should replace a physician's judgement, but in turn be used in conjunction to facilitate decisions on patient care (Agulnik et al 2016). The entire goal of PEWS is to aid the physician and provide a quantitative score to evaluate the patient. It eliminates any bias from other staff members as well as holding the team accountable for documenting patient vital signs.

Due to the fact that this is a clinical audit, the retrospective nature provides a limitation. We relied on documented patient charts, and unfortunately, 9 potential candidates for this study had undocumented PEWS. A number of these patients were admitted from the emergency department, requiring emergency operations. These patients spent minimal time on the wards and therefore their PEWS scores were not documented. PEWS was designed to be measured at the bedside of hospitalized ward patients; however, in the study *Evaluating the Pediatric Early Warning Score (PEWS) System for admitted Patients in the Pediatric Emergency Department* it was also found that elevated PEWS provide medical staff with a signal for transfer to PICU. This suggests the need for a utilization of PEWS or other scoring system in the emergency department.

Unlike the studies mentioned above, our study poses a large degree of heterogeneity, meaning that we evaluated patients from multiple departments, with different clinical conditions, and varying degrees of severity. Due to the specificity of our criteria, our study may have also included PICU patients that may not have been admitted due to elevated PEWS scores. Although their PEWS scores were elevated and documented, they may have been admitted due to surgical complications either during surgery or post-operatively. For instance, a hospitalized female newborn underwent a liver biopsy and unfortunately, during the procedure, the pleura was pierced and resulted in a hemothorax. She therefore qualifies as an unplanned transfer to PICU following surgery, but her

admission was not based on elevated PEWS score. This demonstrates the lack of sensitivity in patient inclusion parameters. Also, two patients that underwent spinal surgery had to have emergency correction surgery following loss of neuronal function. Perhaps refining our patient population would have demonstrated a significant use for PEWS in this context. However, with these added parameters, the patient pool would decrease dramatically. Therefore, future studies may use a multi-hospital, city, or even countrywide parameter in order to better evaluate the correlation of PEWS and these critically ill patients in PICU following surgery. Finally, in order to attain a more statistically significant result, the incorporation of a control group would be necessary. This would provide data on paediatric patients who attended PICU following surgery in a planned manner, as well as comparing the number of patients PEWS scores that were not documented at all.

Conclusion

This study demonstrates that PEWS does not appear to provide an additional signal preoperatively for escalation of care required for patients following surgery. Early identification of patient deterioration is essential to avoiding adverse outcomes and life threatening cardiac and pulmonary arrests. Therefore, future studies may evaluate new scoring systems to better alert health care professionals of possible deteriorations.

Acknowledgements

We would like to thank the following for making this research possible: Our Lady's Children's Hospital Crumlin, Dr. Cormac Breatnach, Dr. Martina Healy, Dr. Sinead Harte, Melanie Kennedy, Erica Brereton, and Avril Hand.

References

Agulnik, Asya & W. Forbes, Peter & Stenquist, Nicole & Rodriguez-Galindo, Carlos & Kleinman, Monica. (2016). Validation of a Pediatric Early Warning Score in Hospitalized Pediatric Oncology and Hematopoietic Stem Cell Transplant Patients. *Pediatric Critical Care Medicine.*

Booth, J., 1977. A short history of blood pressure measurement. *Proceedings of the Royal Society of Medicine*, 70(11), pp.793–799.

Chapman, S.M. et al., 2017. "The Score Matters": Wide variations in predictive performance of 18 paediatric track and trigger systems. *Archives of Disease in Childhood*, 102(6), pp.487–495.

Dean, N.P. et al., 2017. Evaluation of a Pediatric Early Warning Score Across Different Subspecialty Patients. *Pediatric Critical Care Medicine*, 18(7), pp.655–660.

Harnden, A. et al., 2009. Child deaths: confidential enquiry into the role and quality of UK primary care. *The British journal of general practice : the journal of the Royal College of General Practitioners*, 59(568), pp.819–824.

Kyriacos, U. et al., 2014. Monitoring vital signs: Development of a Modified Early Warning Scoring (Mews) system for general wards in a developing country. *PLoS ONE*, 9(1).

Kyriacos, U., Jelsma, J. & Jordan, S., 2011. Monitoring vital signs using early warning scoring systems: A review of the literature. *Journal of Nursing Management*, 19(3), pp.311–330.

L Gold, D., K Mihalov, L. & M Cohen, D., 2014. *Evaluating the Pediatric Early Warning Score (PEWS) System for Admitted Patients in the Pediatric Emergency Department*.

Lockwood C, Bn RN, Clinnurs G, et al. Vital signs. 2004:207-230

McLellan, M.C. & Connor, J.A., 2013. The Cardiac Children's Hospital Early Warning Score (C-CHEWS). *Journal of Pediatric Nursing: Nursing Care of Children and Families*, 28(2), pp.171–178.

Parshuram, C.S. et al., 2018. Effect of a Pediatric Early Warning System on All-Cause Mortality in Hospitalized Pediatric Patients. *Jama*, pp.1–11.

Straney, L. et al., 2013. Paediatric index of mortality 3: An updated model for predicting mortality in pediatric intensive care. *Pediatric Critical Care Medicine*, 14(7), pp.673–681.

Appendix

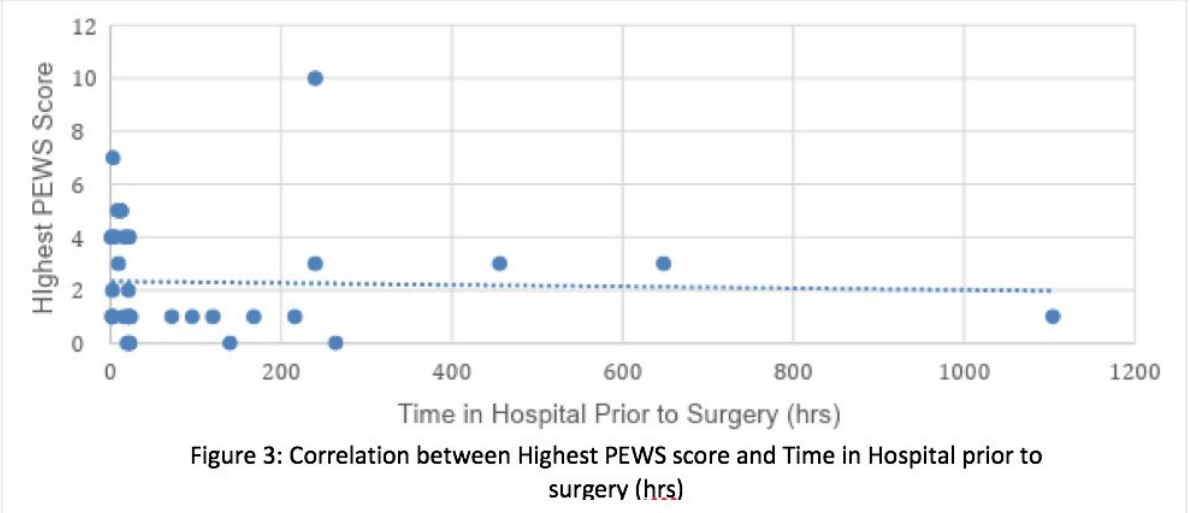

Figure 3: Correlation between Highest PEWS score and Time in Hospital prior to surgery (hrs)

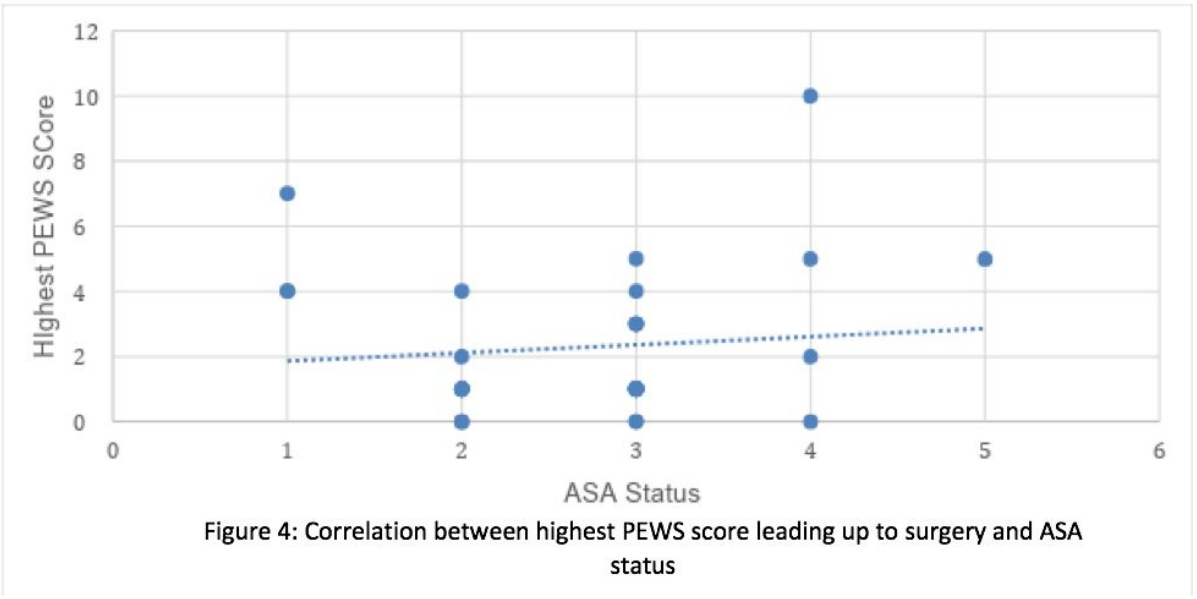

Figure 4: Correlation between highest PEWS score leading up to surgery and ASA status

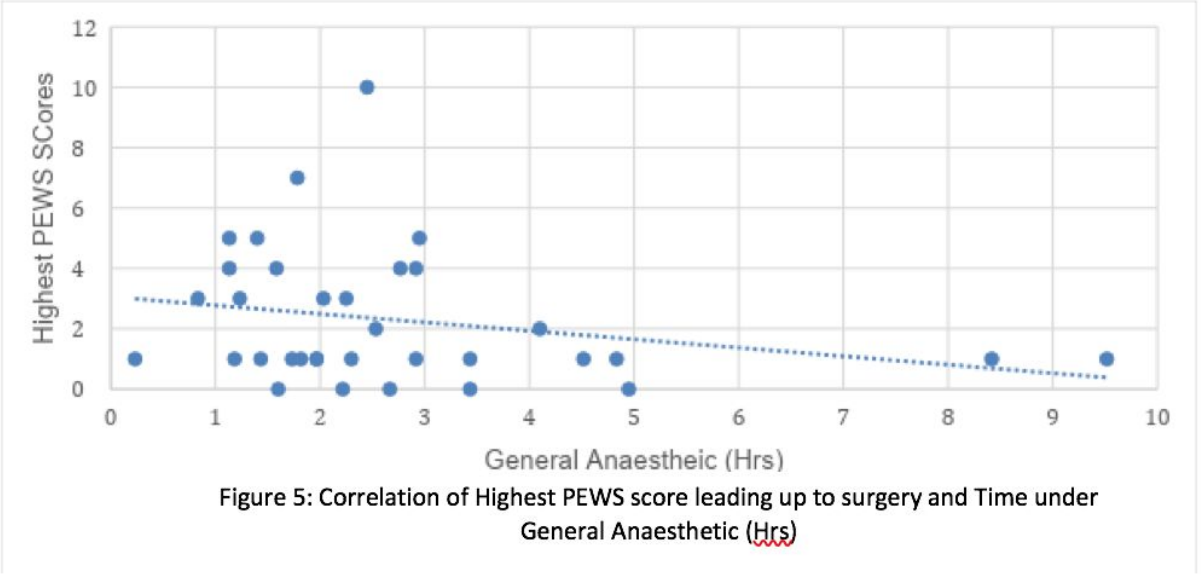

Figure 5: Correlation of Highest PEWS score leading up to surgery and Time under General Anaesthetic (Hrs)

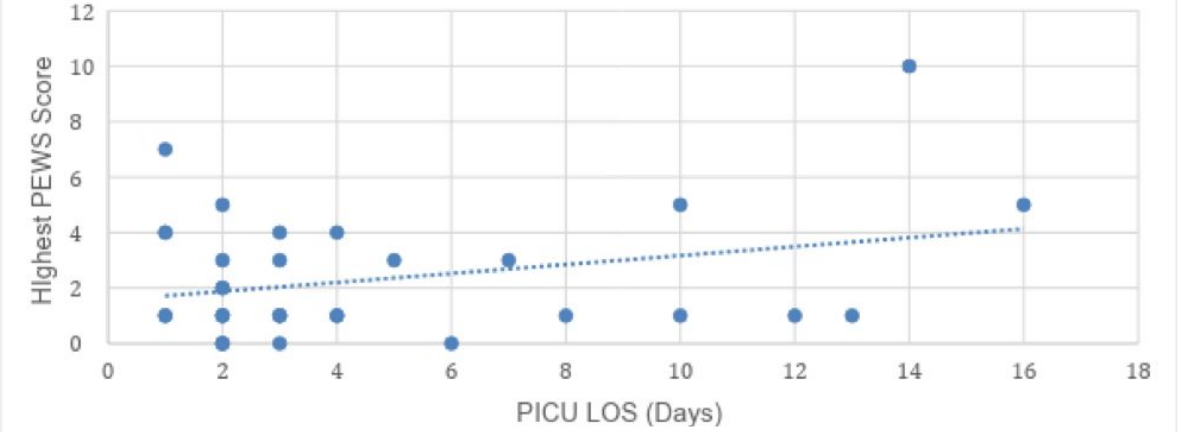

Figure 6: Correlation between Highest PEWS score and PICU Length of Stay (LOS) (days)

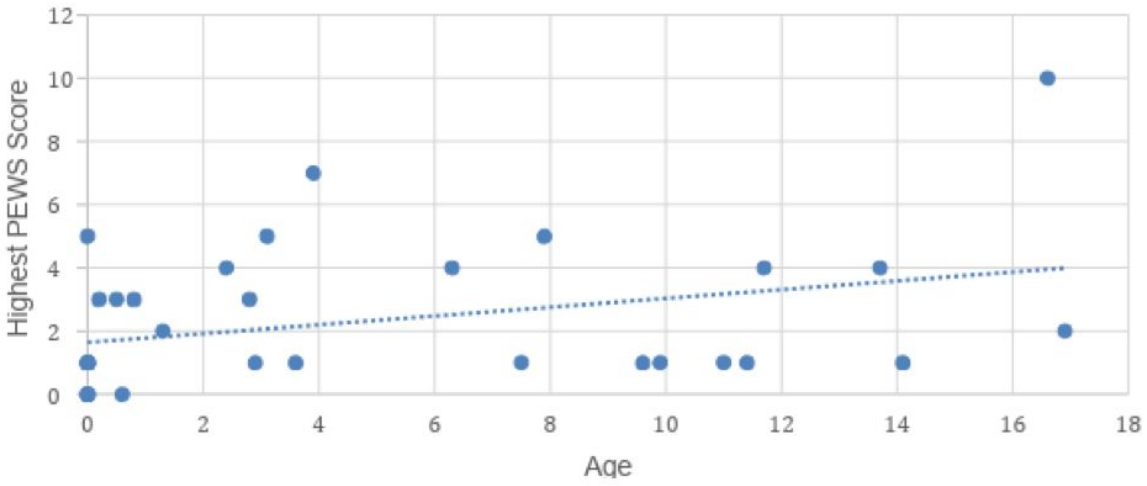

Figure 7: Correlation between Highest PEWS score and Age (yrs.)