

Confirmation was first assessed via auscultation by the anesthetist performing the intubation and was then followed by ultrasound performed by a trained sonographer. Sonography of bilateral lung fields with a 5MHz curvilinear probe was performed looking for lung slide. Unilateral versus bilateral lung slide were used to differentiate between right mainstem bronchus intubation and tracheal intubation. Finally, a fiber optic bronchoscope was inserted to confirm appropriate tube placement. During the above process a researcher was present with ear plugs so as not to overhear the discussion in the room and the tube was covered to not reveal its depth to the researcher.

Sixty-eight adults were recruited. The average age was 60 years old and there was a slight male to female predominance 54% to 46% respectively. Rates of intubation success on first, second, and third attempts were as follows; 54 (79.4%), 10 (14.7%), and 3 (4.4%). There were 58 correct placements, 8 in the right main stem bronchus and 2 in the left mainstem bronchus. Of the 87 attempts there were 12 esophageal intubations (13.8%). Ultrasound was found to be more accurate in determining correct tube placement when compared to auscultation, 85.29% versus 67.6% ($P = .005$). Ultrasound was also more sensitive (84.48% versus 67.24%; $P = .005$) and specific (90.00% versus 70.00%; $P < .001$). They also found a 20% ($P = < .001$) absolute reduction in false positive and 17.24% ($P = .005$) absolute reduction in false negative rates.

The authors concluded that due to the above data, thoracic ultrasound could be incorporated into the repertoire for determining appropriate endotracheal tube placement. They note limitations, including the use of only one sonographer who was highly experienced, which may not always be available and limits generalizability.

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Comments: This study provides us with another potentially useful adjunct that may be utilized in emergency departments, especially as our obese population continues to grow. Tools such as end-tidal CO₂ and colorimetry help confirm placement in the airway as opposed to the esophagus; however, they do not provide indication as to whether or not the tube position within the airway is correct. The clinical applications for ultrasound are rapidly expanding and can be a good adjunct to airway management in scenarios where auscultation is difficult or there is a delay in portable radiography. Further research is needed to determine whether or not ultrasound is more useful than current methods used in determining correct endotracheal tube placement in obese ED patients.

□ DIAGNOSIS OF ELEVATED INTRACRANIAL PRESSURE IN CRITICALLY ILL ADULTS: SYSTEMATIC REVIEW AND META-ANALYSIS.

Fernando SM, Tran A, Cheng W, et al. *BMJ*. 2019; 366:14225 doi:10.1136/bmj.14225

Elevated intracranial pressure (ICP) is a commonly encountered condition due to brain injuries including traumatic brain injury (TBI), subarachnoid hemorrhage (SAH), and intracere-

bral hemorrhage and can result in cerebral ischemia, brain herniation and death if left untreated. Although guidelines recommend invasive ICP monitoring in suspected cases, the diagnostic reliability of physical examination, computed tomography (CT) findings and other non-invasive modalities for detecting increased ICP is unclear.

This systematic review and meta-analysis evaluated the reliability of physical examination, CT, optic nerve sheath diameter (ONSD) sonography, and transcranial Doppler (TCD) for the diagnosis of elevated ICP. Randomized controlled trials as well as retrospective and prospective observational studies of patients ≥ 16 years conducted in emergency departments or intensive care units evaluating the modalities of interest were included. With the assistance of a librarian, the authors searched for English language full text articles from six different databases. Invasive ICP monitoring pressure reading ≥ 20 mm Hg and craniotomy with operative diagnosis were used as reference standards for the diagnosis of elevated ICP. If there was a delay ≥ 1 hour between diagnostic testing and ICP measurement or if the non-invasive testing was completed after invasive ICP measurement, the studies were excluded. Studies underwent screening by two independent reviewers. The same independent reviewers extracted relevant data (true positives, false positives, true negatives and false negatives) which was verified by a third investigator. The quality assessment of diagnostic accuracy studies (QUADAS-2) tool (which evaluates patient selection, index test, reference standard and flow/timing) was used independently by the two reviewers to assess for risk of bias. The GRADE (grading of recommendations, assessments, development, and evaluation) approach was used to evaluate confidence in pooled diagnostic calculations.

After screening 2570 studies, a total of 40 studies were included in the meta-analysis, providing a total of 5123 patients. TBI and SAH accounted for the majority of the data, at 64.5% ($n=3304$) and 14.3% ($n=731$) of patients, respectively. Studies deemed at high risk of bias included those that used intraoperative diagnosis of elevated ICP (4 studies), epidural pressure monitoring (1 study), and lack of blinding to ICP monitor results (2 studies). Pupillary dilation, motor posturing (Glasgow coma scale (GCS) motor score ≤ 3), and decreased level of consciousness (LOC; GCS ≤ 8) were the only physical examination findings with sufficient data for meta-analysis. The sensitivity and specificity for diagnosis of elevated ICP was 28.2% (95% CI, 16% - 44.8%) and 85.9% (95% CI, 74.9% - 92.5%) respectively for pupillary dilation, 54.3% (95% CI, 36.6% - 71%) and 63.6% (95% CI, 46.5% - 77.8%) respectively for motor posturing, and 75.8% (95% CI, 62.4% - 85.5%) and 39.9% (95% CI, 26.9 - 54.5%) respectively for decreased LOC. CT findings included absence or compression of basal cisterns (sensitivity 85.9% (95% CI, 58 - 96.4%) and specificity 61.0% (95% CI, 29.1% - 85.6%)), any midline shift (sensitivity 80.9% (95% CI, 64.3% - 90.9%) and specificity 42.7% (95% CI, 24% - 63.7%)) and midline shift ≥ 10 mm (sensitivity 20.7% (95% CI, 13% - 31.3%) and specificity 89.2% (95% CI, 77.5% - 95.2%)). The Marshall classification system was also assessed with Marshall class ≥ 3 demonstrating a sensitivity of 80.6% (95% CI, 63.5% - 90.9%) and specificity 59.9% (95%



CI, 40.9% - 76.4%). Specificity increased to 83.5% (95% CI, 70.4% - 91.5%) for Marshall class of ≥ 5 . ONSD sonography had a pooled AUROC of 0.94 (95% CI, 0.91% to 0.96%) in detection of elevated ICP based on ten studies, but there was heterogeneity of ONSD thresholds between studies. AUROC values for both Transcranial Doppler pulsatility index (TCD-PI) and arterial blood pressure (TCD-ABP) were calculated. However, AUROC values for TCD-PI indicated that pooling the data was inappropriate. The three studies examining TCD-ABP yielded a pooled AUROC of 0.85 (95% CI, 0.78 to 0.91).

Given current guidelines advocating for treatment of ICP > 20-25 mm Hg, and the potential complications of invasive monitoring, non-invasive diagnostic strategies for determining elevated ICP would be beneficial. The authors concluded that they were unable to identify any single modality capable of detecting elevated ICP with sufficient sensitivity. Although many studies have used CT findings as a reference standard, this study demonstrates that reliance on CT alone would result in a significant number of missed cases. Although ONSD sonography and TCD-ABP show promising results, further research is needed as sensitivity and specificity could not be calculated. The authors note several limitations of the study, such as a lack of standardized approach to diagnosing elevated ICP, possible spectrum bias, inclusion of intraoperative measurements, among others. Since the examined diagnostic modalities failed to significantly increase the post-test probability of elevated ICP, the authors recommend that physicians not exclusively rely on them in isolation to make their clinical decisions. Physicians should consider the overall clinical picture of the patient and consider empiric treatment with invasive monitoring if elevate ICP is a concern.

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Comment: This study demonstrates the difficulty in identifying patients with elevated ICP through non-invasive modalities and as a result, that patients where there is a high clinical suspicion should undergo invasive ICP monitoring. Clinicians at facilities lacking capability of invasive ICP monitoring should advocate for patient transfer if there is any concern for elevated ICP. We agree with the authors in that further research to establish a clinical decision instrument for more accurate risk stratification could be beneficial. Additionally, more definitive ONSD thresholds combined with further research may be particularly beneficial to the emergency medicine clinician.

□ **ASSOCIATION OF BLOOD COMPONENT RATIOS WITH 24-HOUR MORTALITY IN INJURED CHILDREN RECEIVING MASSIVE TRANSFUSION.**

Butler EK, Mills BM, Arbabi S, et al. *Crit Care Med* 2019;47(7):975-983

Trauma resuscitation in unstable adult and pediatric trauma patients consists of controlling bleeding, limiting crystalloids, permissive hypotension, and balanced blood transfusion. In

adults it is commonly accepted that a 1:1:1 ratio of fresh frozen plasma (FFP), platelets, and packed red blood cells (PRBCs) is the ideal balance of blood products, however this has not been well studied in pediatric patients and is unknown.

The purpose of this study was to determine if a specific ratio of blood products in pediatric trauma patients is associated with improved survival at 24 hours. In this retrospective cohort study, the Pediatric Trauma Quality Improvement Program Database was reviewed for pediatric patients aged 14 years old or younger who sustained a traumatic injury requiring massive transfusion between 2014 and 2016. The database includes patients from level 1 and level 2 trauma centers within the United States. Massive transfusion was defined as receiving greater than or equal to 40 ml/kg of total blood products in the first 24 hours. Exclusion criteria included death within the first 30 minutes of arrival to the hospital, unknown outcomes, and those who did not receive PRBCs during massive transfusion. The blood products were evaluated based on ratios of FFP:PRBC and platelets:PRBC. Within each of these groups, they were subcategorized by the amount of the ratios. For FFP:PRBC, they were subcategorized into low (<1:2), medium ($\geq 1:2$ and <1:1), and high ($\geq 1:1$). For platelet:PRBC there was significantly less platelets given overall so they were subcategorized into none (0), low (>0 and <1:2), and high ($\geq 1:2$). The primary outcome was 24-hour mortality. Secondary outcomes included were in-hospital mortality, any complication, hospital length of stay (LOS), intensive care unit (ICU) LOS, number ventilator days, and hospital disposition.

Five hundred and eighty three patients were included in the study. Overall, the average age was 5 years old, 60% of the patients were males, and the majority of the injuries were blunt trauma (73.8%). At 24 hours, overall mortality was 19.7% (95% CI, 16.6-23.2). Using the low FFP:PRBC group as a reference group, the medium group had an aRR of 0.60 (95% CI, 0.39-0.92) and the high group was 0.49 (0.27-0.87). The overall 24 hour mortality aRR for platelet:PRBC was 0.94 (95% CI, 0.51-1.71). Using the no platelet:PRBC group as a reference group, the low group had an aRR of 1.29 (95% CI, 0.81-2.05) and the high group was 1.04 (95% CI, 0.52-2.09). Overall the complication rate was low at 15.6% with the only statistically significant complications being deep venous thrombosis in those receiving FFP with an aRR of 1.77 (95% CI, 1.22-2.57) and pneumonia in those receiving platelets with an aRR of 1.94 (95% CI, 1.14-3.28). The only statistically significant secondary outcome was a decreased in hospital mortality in those receiving FFP with an aRR 0.72 (95% CI, 0.55-0.96). The limitations of this study include possible type 2 error of the platelet analysis as well as the analysis of the complications as there was a very low number of both. Survival bias is also a potential limitation which they attempted to account for by excluding patients that died early in their ED course. Finally, the database used in this study did not include information on other therapies that could potential affect outcomes such as use of tranexamic acid, recombinant factor VIIa, or volume of crystalloid administration.

The authors concluded that pediatric trauma patients had an improved mortality with higher ratios of FFP:PRBC when

