oximetry monitoring in the prehospital environment for patients with moderate to severe TBI.

Patients with moderate to severe TBI often require advanced airway management, a procedure that exposes patients to additional secondary insults, particularly in the absence of appropriate hemodynamic, oxygenation, and ventilation monitoring. The importance of close monitoring of oxygen saturation was documented in a study of patients in San Diego with suspected TBI undergoing rapid sequence intubation (RSI) in the prehospital setting (25). Each of the 59 patients was matched to three historical nonintubated control patients. Investigators documented the occurrence, timing, and duration of hypoxic episodes and found that profound hypoxia (SpO_2 <70%) and any single desaturation <90% was associated with higher mortality (OR 3.89, 95%CI 1.12–13.52 and 3.86, 95%CI 1.18–12.61, respectively) compared to matched controls. Given these findings, patients with significant TBI requiring intubation should undergo continuous pulse oximetry monitoring to allow for rapid correction of hypoxia.

Hypotension reduces cerebral perfusion pressure to the injured brain and has a profoundly negative effect on outcome for patients with moderate to severe TBI. A prospectively collected dataset from the Traumatic Coma Data Bank demonstrated that prehospital hypotension (defined as a single SBP less than 90 mmHg) and hypoxemia (defined as apnea, cyanosis, or oxygen saturation <90%) in the field were powerful predictors of patient outcome. In particular, a single episode of hypotension was associated with a two-fold increase in mortality in matched cohorts without hypotension (26).

The EPIC study evaluated the effect of implementing prehospital TBI guidelines for patients with moderate to severe TBI across the state of Arizona (15). This large, observational study linked to the Arizona State Trauma Registry and discussed further in the *Airway* section, evaluated 13,151 patients with prehospital TBI, and concluded that in the pre-implementation cohort, odds of death were higher with prehospital hypotension (OR 2.49, 95%CI 1.87–3.32) and hypoxia (OR 3.00, 95%CI 2.37–3.78). Importantly, the study demonstrated that the combined effect of both hypotension and hypoxia was associated with significant mortality (43.9%) and an adjusted odds ratio for death of 6.1 (95%CI 4.20–8.86).

The poor outcomes in TBI patients associated with single episodes of hypotension have been confirmed in multiple studies including EPIC. However, newer data from the EPIC study suggest that hypotension dose (defined as depth-duration dose of hypotension <90 mmHg integrated over time in minutes) is also associated with increased mortality in patients with TBI, with mortality rates exceeding 50% in patients with markedly prolonged episodes of hypotension (27,28). These findings highlight the importance of frequent blood pressure monitoring in the prehospital environment.

The value of 90 mmHg systolic pressure to delineate the threshold for hypotension arose in more of a statistical than physiologic parameter. In considering the evidence concerning the influence of cerebral perfusion pressure on patient outcome with TBI, it is possible that systolic pressures significantly >90 mmHg may be beneficial during the prehospital and resuscitation phase of care. Since the writing of the prior update, several studies have addressed the issue of a hypotension threshold for TBI patients. The EPIC study specifically reported that across the blood pressure range of 40 mmHg to 119 mmHg in the prehospital setting, each 10-point increase in SBP was associated with a decrease in the adjusted odds ratio of death by 18.8% (adjusted OR, 0.812; 95%CI 0.748–0.883) (7). Importantly, the study demonstrated that there was no identified threshold or inflection point within the range, and that the historic use of 90 mmHg may be incorrect, as decreased mortality rates were significantly associated with higher values.

Age may play a role in defining the optimal blood pressure threshold after TBI. Investigators from Japan evaluated the Japan Trauma Data Bank for in-hospital mortality for patients with severe TBI in an attempt to identify specific blood pressure thresholds. After studying on-arrival blood pressures in 12,537 patients, the investigators advocated for a threshold modified by age in which patients younger than 61 years are considered hypotensive at a SBP <100 mmHg, whereas older patients are considered hypotensive at a SBP <120 mmHg. The investigators identified a SBP of 110 mmHg as the optimal threshold for hypotension with adjusted odds ratio for mortality on admission of 1.58 (95%CI 1.46–1.76, $p < 0.001$) (29). In 2021, Shibahashi et al. analyzed 34,175 patients with TBI and reported that SBP < 110 mmHg was significantly associated with in-hospital mortality (14).

Extremes of blood pressure, including hypertension, may have significant negative physiological consequences for patients with TBI. The concept of paroxysmal sympathetic hyperactivity is seen in patients after severe TBI and is associated with elevated catecholamines resulting in hypertension and other negative effects (30). Three studies included in this update reflect the importance of monitoring and awareness of hypertension in the prehospital setting (17,31). A retrospective review 305,503 TBI patients from the National Trauma Data Bank reported that adjusted odds for mortality was 1.33 for prehospital SBP of 160–180 mmHg (95%CI 1.22–1.44, $p < 0.001$) and 1.97 for prehospital SBP of 190–230 mmHg (95%CI 1.76–2.21, $p < 0.001$) (17). Similar findings were reported in a German study, which retrospectively evaluated 8,788 patients with TBI from the German Society for Trauma Surgery Registry from 1993 to 2008 (31). The primary variables of interest were prehospital SBP greater than 160 mmHg versus less than 160 mmHg. The investigators reported that in patients with TBI and hypertension (>160 mmHg) there was significantly higher incidence of mortality compared to normotensive patients (25.3% vs. 13.5%, $p < 0.001$). Overall, the study reported that prehospital hypertension >160 mmHg had an odds ratio of 1.9 (95%CI 1.4–1.6) for in-hospital mortality compared to normotensive patients.

The available data regarding TBI underscore the importance of frequent prehospital monitoring (at least every 5 minutes) in order to anticipate, prevent, and rapidly correct hypoxia, hypotension, and hypertension in patients with suspected TBI. This requires the thoughtful and intentional implementation of continuous monitoring practices across