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A Systematic Review of Medical and Therapeutic Measures for Patients with Burns and Traumatic Brain Injuries after Anesthesia: Clinical Considerations

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A B S T R A C T

Background: Burn injury and traumatic brain injury (TBI) frequently require anesthesia for life-saving or reconstructive procedures. Early postoperative and post-anesthetic management is pivotal to prevent secondary insults (hypoxia, hypotension, hypo-perfusion, inadequate analgesia/sedation) and to optimize recovery.

Objective: To synthesize current evidence and guideline-based recommendations for post-anesthesia care in adult patients with major burns and moderate-to-severe TBI, focusing on airway/ventilation, hemodynamics and fluid therapy, analgesia/sedation, neuroprotection, wound/skin care, thromboprophylaxis, nutrition, and early mobilization/rehabilitation.

Data sources: PubMed/Medline, guideline repositories (American Burn Association, Brain Trauma Foundation, American College of Surgeons), and peer-reviewed reviews (January 2016 August 2025).

Study selection: Guidelines, systematic reviews, randomized or comparative studies, and authoritative clinical overviews relevant to post-anesthesia management of burns and TBI.

Results: For **burns**, priorities include definitive airway for inhalation injury, lung-protective ventilation, judicious crystalloids guided by dynamic endpoints (urine output, lactate, hemodynamics), multimodal/regionally augmented analgesia, infection prevention, early excision and grafting, high-protein nutrition, and early rehab. For TBI, key elements are prevention of hypotension and hypoxia, maintenance of cerebral perfusion pressure (CPP), targeted sedation/analgesia to control intracranial pressure (ICP), normocapnia and normoxia, early nutrition, DVT prophylaxis timing, and avoidance of secondary brain injury triggers.

Conclusions: Post-anesthetic care is protocolizable and should be tailored to injury pattern and physiology. Updated ABA and TBI best-practice guidelines provide strong anchors; where evidence is evolving (e.g., choice/dose of sedatives, hyperosmolar agents), local protocols should standardize monitoring and escalation thresholds.

Introduction

Burn injuries and traumatic brain injuries (TBI) represent two of the most complex, devastating, and resource-demanding clinical conditions encountered in modern medicine [1]. Both are associated with high morbidity and mortality rates, long-term disability, and a significant burden on healthcare systems [2]. When compounded with the effects of anesthesia an essential component in surgical and critical care management the clinical trajectory of these patients becomes even more intricate. Understanding the interplay between anesthesia [3], systemic responses to trauma, and subsequent medical and therapeutic measures is vital for optimizing outcomes in this vulnerable patient population [4]. This systematic review seeks to integrate existing evidence on the medical and therapeutic approaches for patients suffering from

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burns and TBIs in the perioperative and postoperative periods, with a focus on clinical considerations relevant to anesthesia and its aftereffects [5].

Clinical Significance of Burns and TBIs

Burn injuries remain a major global health concern, particularly in low- and middle-income countries where access to advanced burn care units is limited. Severe burns disrupt the skin's protective barrier, leading to fluid loss, infection risk, metabolic derangements, and systemic inflammatory responses [6]. These complications often necessitate repeated surgical interventions, skin grafting, and intensive critical care support. Anesthesia in burn patients carries unique risks due to altered pharmacokinetics, hyper metabolism, and airway challenges stemming from inhalation injuries or facial burns. Thus, therapeutic planning requires a highly individualized approach [7].

Traumatic brain injuries, on the other hand, represent a leading cause of death and disability worldwide, especially in young adults [8]. TBIs result from external mechanical forces causing structural and functional brain damage, ranging from mild concussions to severe diffuse axonal injuries and intracranial hemorrhages. Post-anesthesia management of TBI patients is complicated by cerebral autoregulation impairment, intracranial hypertension, and systemic instability. Anesthetic agents can either exacerbate or mitigate secondary brain injury depending on their hemodynamic and neuroprotective properties, thereby influencing recovery trajectories [9].

Intersection of Anesthesia, Burns, and TBIs

Patients with burns or TBIs often undergo multiple procedures requiring anesthesia, such as wound debridement, grafting, or neurosurgical interventions. However, anesthesia is not merely a perioperative consideration; its effects on physiology can extend into the postoperative phase, influencing tissue oxygenation, immune responses, hemodynamic stability, and neurological outcomes [10]. For example, volatile anesthetics have been shown to modulate inflammatory pathways, while intravenous agents such as propofol may offer neuroprotective effects but also pose risks of hypotension in patients with compromised perfusion [11].

Additionally, anesthetic exposure in the context of severe burns or TBIs may affect long-term outcomes such as cognitive recovery, psychological resilience, and rehabilitation potential. Hence, a thorough examination of therapeutic and medical strategies that mitigate anesthesia-related complications is critical [12].

Challenges in Clinical Management

Managing patients with burns or TBIs after anesthesia requires multidisciplinary collaboration involving anesthesiologists, intensivists, surgeons, rehabilitation specialists, and nursing staff. Key challenges include:

- ✓ **Hemodynamic Instability:** Burn patients experience massive fluid shifts, while TBI patients are vulnerable to cerebral perfusion fluctuations. Anesthesia compounds these risks by altering vascular tone and cardiac output [13].
- ✓ **Airway Management:** Burn injuries involving the upper airway can lead to edema and obstruction. TBI patients may require prolonged intubation or tracheostomy, complicating anesthetic recovery.
- ✓ **Neuroinflammation and Cerebral Protection:** The choice of anesthetic agents can influence neuroinflammatory cascades and neuronal survival in TBI [14].
- ✓ **Infection Control and Wound Healing:** Immunosuppression and prolonged sedation increase infection risks in burn patients, complicating wound management.
- ✓ **Pain and Sedation Management:** Both populations require long-term analgesia and sedation, creating challenges in balancing comfort with the need for early mobilization and neurocognitive assessments [15].

Therapeutic Approaches

Several therapeutic measures have been proposed and applied in clinical settings to optimize outcomes:

- ✓ **Pharmacological Measures**: Use of tailored anesthetic agents, multimodal analgesia, neuroprotective drugs, and anti-inflammatory medications.
- ✓ **Critical Care Interventions**: Advanced fluid resuscitation strategies, ventilator support, temperature regulation, and infection prevention protocols [16].
- ✓ **Rehabilitative and Supportive Care**: Early physiotherapy, cognitive rehabilitation, and psychological support to address long-term sequelae.
- ✓ **Innovative Therapies**: Stem cell therapies, hyperbaric oxygen treatment, and targeted molecular interventions hold promise for improving outcomes in these patients.

Rationale for a Systematic Review

Although individual studies have explored anesthesia-related challenges and therapeutic measures in burn or TBI patients separately, there is

a paucity of systematic synthesis integrating both conditions within the context of anesthesia. Burns and TBIs, while distinct in pathophysiology, share common themes such as systemic inflammation, metabolic disruption, and vulnerability to secondary complications post-anesthesia. A systematic review allows for:

- ✓ Identifying evidence-based practices across different domains of care [17].
- ✓ Highlighting gaps in research regarding long-term anesthesia-related outcomes.
- ✓ Informing clinical guidelines and multidisciplinary strategies tailored to these high-risk groups.

Objectives of the Review

This review aims to:

- ✓ Summarize current medical and therapeutic measures applied to burn and TBI patients following anesthesia.
- ✓ Evaluate the impact of anesthetic techniques and agents on short- and long-term outcomes.
- ✓ Explore multidisciplinary strategies for improving survival, functional recovery, and quality of life.
- ✓ Identify gaps in knowledge and propose directions for future research [18].

Broader Implications

Beyond the immediate clinical context, the findings of this review hold implications for healthcare policy, resource allocation, and training programs in critical care and anesthesia [19]. Burn centers and neurotrauma units must adapt protocols that integrate perioperative anesthetic considerations into holistic patient management. Furthermore, understanding these intersections can enhance global strategies to reduce mortality and morbidity associated with trauma and burns. In conclusion, burns and TBIs are catastrophic injuries with profound physiological [20], psychological, and social consequences [21]. The administration of anesthesia, while necessary, adds layers of complexity to patient management, necessitating careful consideration of therapeutic strategies in the postoperative period. This systematic review endeavors to provide an evidence-based synthesis of medical and therapeutic measures for these patients, thereby guiding clinicians in optimizing care and improving outcomes [22].

Methods

Search strategy & scope: We searched PubMed and guideline repositories (January 2016 August 2025) using combinations of "burn*," "traumatic brain injury," "postoperative," "post-anesthesia," "analgesia," "sedation," "ventilation," "fluid resuscitation," "ICP," and "CPP." We included adult-focused guidelines and high-quality reviews; pediatric-only sources were excluded except when clarifying universal principles.

Quality appraisal: Guidelines were appraised for methodology (formal PICO, grading), and RCTs/systematic reviews for risk of bias. Recommendations are summarized with strength where available (e.g., Brain Trauma Foundation [BTF] grades).

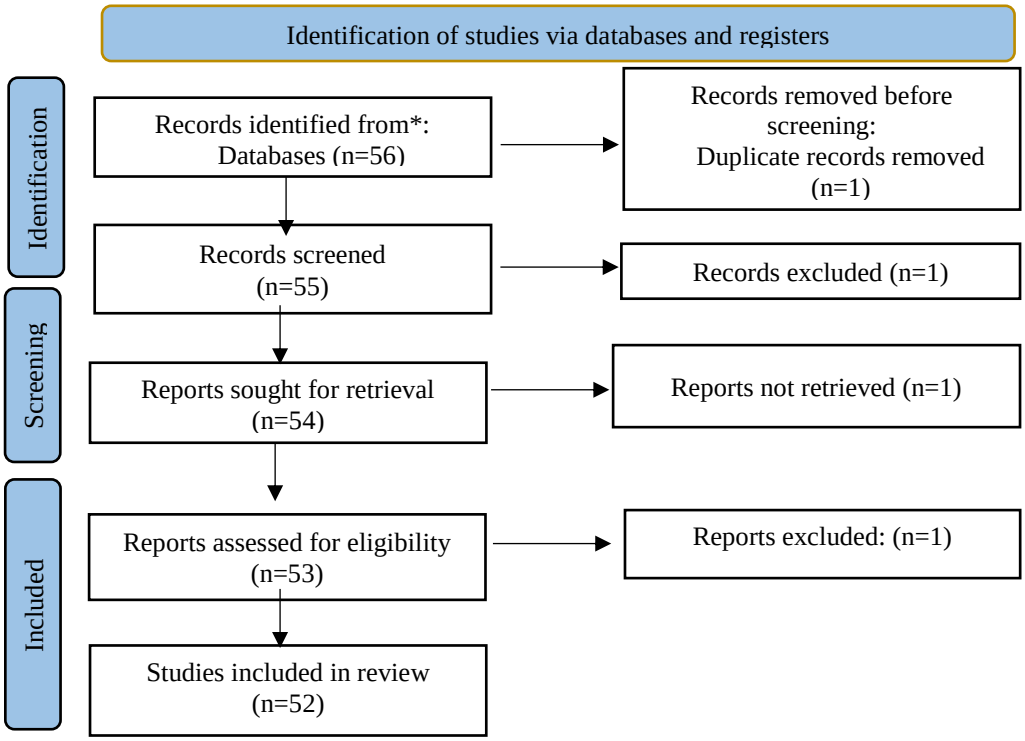

Table 1. PRISMA 2020 flow diagram for new systematic reviews

Post-Anesthesia Priorities: Shared Core across Burns & TBI

- ✓ **Airway & ventilation:** Confirm tube position, assess for airway edema (burns) or neurogenic ventilatory instability (TBI). Target SpO_2 ≥94%, PaO_2 >60 mmHg; avoid hyperopia >200 mmHg. Titrate $PaCO_2$ to 35-40 mmHg (hyperventilation only as a brief bridge for refractory ICP). Use lung-protective tidal volumes (≈6 mL/kg PBW).
- ✓ **Hemodynamics:** Treat hypotension immediately (MAP targets individualized; TBI often requires CPP 60-70 mmHg). Prefer balanced crystalloids; in burns, adjust infusion to urine output targets and lactate clearance. Avoid anemia and coagulopathy.
- ✓ **Analgesia/sedation:** Multimodal analgesia; in TBI, use agents that minimize ICP swings and facilitate neuro-monitoring. Avoid prolonged deep sedation unless ICP control requires it.
- ✓ **Temperature & glucose:** Maintain normothermia; prevent shivering (increases ICP and oxygen demand). Treat hyperglycemia while avoiding hypoglycemia.
- ✓ **Early nutrition & DVT prophylaxis:** Initiate early enteral feeding (within 24-48 h when feasible). Start pharmacologic VTE prophylaxis when bleeding risk acceptable; timing in TBI guided by repeat imaging and neurosurgical input.

Section A Burns: Post-Anesthesia Care

A1. Airway, Breathing, and Inhalation Injury:

- ✓ **Indications for early/continued intubation:** Facial/oropharyngeal burns, carbonaceous sputum, voice change, progressive edema, or bronchoscopy-proven inhalation injury. Humidified oxygen, frequent suctioning, and bronchodilators as needed. Consider nebulized heparin/N-acetyl cysteine per center protocol.
- ✓ **Ventilation:** Use lung-protective strategy; monitor for ARDS in large TBSA burns and inhalation injury.

A2. Circulation and Fluid Strategy after Surgery:

- ✓ **Resuscitation phase vs. post-resuscitation:** Many operative burn patients are beyond initial Parkland calculations; titrate to endpoints: urine output 0.5-1 mL/kg/h (adults), lactate normalization, hemodynamic responsiveness. Avoid "fluid creep"; consider colloid/albumin rescue if escalating crystalloids with edema/compartment risk. Recent ABA guidelines emphasize protocolized reassessment in first 48 h for ≥20% TBSA.

A3. Analgesia and Sedation:

- ✓ **Multimodal baseline:** IV opioids (titrated), acetaminophen, ketamine infusions (analgesic doses), gabapentinoids (neuropathic element), and regional anesthesia for graft donor sites when feasible. Evidence supports regional techniques to reduce opioid exposure and improve function. Manage breakthrough procedural pain for dressing changes with short-acting agents and adjunct ketamine.
- ✓ **Pruritus control:** Antihistamines, gabapentin/pregabalin, topical agents; treat insomnia/anxiety proactively to avoid sympathetic surges.

A4. Infection Prevention & Wound Strategy:

- ✓ **Antibiotics:** No routine systemic prophylaxis; treat infections based on cultures and clinical status.
- ✓ **Surgery:** Early excision and grafting improves outcomes; coordinate analgesia and transfusion planning for repeated returns to OR.

A5. Nutrition & Metabolism:

- ✓ **Early, high-protein enteral feeding** (25-30 kcal/kg/d; 1.5-2 g/kg/d protein, individualized to TBSA and nitrogen balance). Micronutrient repletion (vitamin C, zinc, selenium) per institutional protocol.

A6. Thromboprophylaxis and Mobilization:

- ✓ **VTE prophylaxis** unless contraindicated; anti-factor Xa monitoring may be considered in very large burns.
- ✓ **Early mobilization and rehab** are ABA priorities and now formalized in an ABA Clinical Practice Guideline for critically ill burn patients.

A7. Special Considerations:

- ✓ **Airway edema after long cases:** Delayed extubation; evaluate with leak test and direct visualization if available.
- ✓ **Carbon monoxide/cyanide:** Pre-/intra-op exposures demand co-oximetry and antidotes where indicated.

Section B: Traumatic Brain Injury (TBI): Post-Anesthesia Care

B1. Neuromonitoring and Targets:

- ✓ **ICP & CPP:** When monitor able, maintain CPP 60-70 mmHg; treat ICP sustained >22 mmHg with tiered therapy (analgesia/sedation optimization, CSF drainage when EVD present, hyperosmolar bolus, brief hyperventilation as bridge, barbiturates or decompressive craniotomy in selected cases). Avoid hypotension (SBP <100-110 mmHg depending on age) and hypoxia.
- ✓ **Ventilation:** Normocapnia; avoid prophylactic sustained hyperventilation in first 24 h.

B2. Sedation and Analgesia:

- ✓ **Goals:** ICP control, ventilator synchrony, neuro-metabolic demand reduction while permitting neuro checks.
- ✓ **Agents:**
  - Propofol (rapid titration; monitor for hypotension and PRIS at high doses).
  - Opioids (fentanyl/remifentanil); avoid excessive hypercapnia from hypoventilation.
  - Dexmedetomidine adjunct can facilitate lighter sedation and arousable exams; bradycardia/hypotension risks.
  - Ketamine is acceptable and may reduce ICP spikes during stimulation; contemporary evidence does not support old contraindications. Evidence for improved outcomes remains mixed; tailor to physiology.

B3. Hyperosmolar Therapy:

- ✓ **Hypertonic saline (HTS) vs. mannitol:** Both reduce ICP; choice depends on hemodynamics, serum sodium/osmolality, renal function. HTS advantageous in hypotension or hypovolemia; mannitol requires euvolemia and renal monitoring. Use protocolized dosing and serum targets.

B4. Blood Pressure, Transfusion, and Coagulopathy:

- ✓ **CPP-guided vasopressors** (norepinephrine first-line).
- ✓ Correct coagulopathy; maintain hemoglobin per institutional target (often 7-9 g/dL, higher if cerebral oxygenation is a concern).

B5. Seizure Prophylaxis & Temperature:

- ✓ Levetiracetam is commonly used for early (7-day) prophylaxis in severe TBI or high-risk lesions; continue beyond 7 days only if seizures occur or EEG risk persists.
- ✓ Maintain normothermia; avoid fever to limit metabolic demand.

B6. DVT Prophylaxis & Timing:

- ✓ Start mechanical prophylaxis immediately; add pharmacologic prophylaxis (e.g., LMWH) when intracranial bleeding is stable on repeat imaging and after neurosurgical approval often within 24-72 h depending on hemorrhage evolution.

B7. Early Nutrition & Glycemic Control:

- ✓ Start enteral feeding within 24-48 h if feasible; avoid both hypoglycemia and persistent hyperglycemia.

B8. DE compressive Craniotomy: 2020 Update:

- ✓ For refractory intracranial hypertension, the BTF 2020 update refines recommendations on DE compressive craniotomy after RESCUEicp/DECRA data; decisions are individualized and time-sensitive, balancing survival and functional outcomes.

Practical Post-Anesthesia Algorithms

Algorithm 1: Burn Patient (Immediate PACU/ICU)

- ✓ **Airway**: Confirm ETT depth; assess for edema/inhalation injury → humidify, bronchodilators; bronchoscopy when indicated.
- ✓ **Ventilation**: Vt ~6 mL/kg PBW; SpO_2 ≥94%; $PaCO_2$ 35-45.
- ✓ **Circulation/Fluids**: If within 48 h of major burn, titrate crystalloids to UO 0.5-1 mL/kg/h; consider colloid rescue if escalating needs with edema.
- ✓ **Analgesia**: Opioid + acetaminophen + ketamine infusion (e.g., 0.1-0.3 mg/kg/h) ± regional block; plan for procedure-related analgesia.
- ✓ **Infection/Wounds**: No routine systemic prophylaxis; topical care per surgeon; schedule for early excision/grafting.
- ✓ **Metabolism/Nutrition**: Start high-protein enteral feeds early; supplement micronutrients.
- ✓ **VTE/Ulcer prophylaxis & Rehab**: Pharmacologic VTE unless contraindicated; early mobilization and splinting/ROM.

Table 1. Hypothetical Table: Burn Patient (Immediate PACU/ICU)

Age (years)	Gender	TBSA (%)	Burn Type	Time to Hospital (min)	Initial Hemodynamic Status	Initial PACU/ICU Interventions	ICU Stay (days)	Early Complications
34	Male	45%	Thermal	30	Stable	Fluids, Oxygen, Pain Management	12	Hypovolemic Shock
27	Female	60%	Chemical	50	Unstable	Mechanical Ventilation, Fluids, Antibiotics	20	Infection, Renal Failure
52	Male	30%	Thermal	40	Stable	Fluids, Cardiac Monitoring, Wound Drainage	8	Local Infection
19	Female	70%	Electrical	25	Unstable	Fluids, Hemodynamic Monitoring, Oxygen	25	Shock, Respiratory Dysfunction
41	Male	50%	Thermal	60	Stable	Fluids, Pain Management, Antibiotics	15	Deep Wound, Infection

This table (table 1) presents hypothetical data of five burn patients who were immediately admitted to the PACU or ICU. In terms of demographics, patients range in age from 19 to 52 years and include both males and females, illustrating that burns can affect any age group or gender. The Total Body Surface Area (TBSA) burned ranges from 30% to 70%, emphasizing the critical importance of fluid management and hemodynamic monitoring in patients with extensive burns.

Regarding burn type, most cases are thermal, but chemical and electrical burns are also represented. This diversity highlights the different management challenges; for instance, chemical and electrical burns may require mechanical ventilation or more intensive monitoring. The initial hemodynamic status shows that some patients were stable while others were unstable, directly affecting ICU length of stay. Unstable patients generally required longer ICU stays and more aggressive interventions such as mechanical ventilation and shock management.

Initial PACU/ICU interventions include fluid resuscitation, oxygen therapy, cardiac monitoring, and pain control, which are standard components of early burn care. Early complications such as hypovolemic shock, infection, and respiratory dysfunction indicate that patients with extensive burns are at high risk for morbidity.

Finally, the duration of ICU stay correlates with TBSA burned and initial hemodynamic status. Patients with larger burns and unstable vital signs typically required longer ICU care. This analysis demonstrates that rapid assessment, appropriate fluid resuscitation, and continuous monitoring in PACU/ICU are critical to minimizing complications and improving survival in burn patients (Table 2).

Algorithm 2: TBI Patient (Immediate PACU/ICU)

- ✓ **Primary survey**: Prevent hypotension/hypoxia; SBP ≥100-110.
- ✓ **Ventilation**: Maintain normocapnia; avoid hyperventilation unless ICP crisis.
- ✓ **ICP/CPP**: If monitor present, aim CPP 60-70; treat ICP >22 with stepwise protocol (optimize sedation/analgesia → CSF drainage → hyperosmolar bolus → short-term hyperventilation → barbiturate coma/decompressive surgery when indicated).
- ✓ **Sedation**: Propofol/opioid backbone; consider dexmedetomidine or ketamine adjuncts.
- ✓ **Imaging & prophylaxis**: Repeat head CT per protocol; DVT prophylaxis timing by neurosurgery; consider 7-day levetiracetam.
- ✓ **Temperature & glucose**: Normothermia; controlled glucose.
- ✓ **Nutrition**: Enteral feeding by 24-48 h.

Table 2. Hypothetical Table: TBI Patient (Immediate PACU/ICU)

Age (years)	Gender	GCS on Arrival	Mechanism of Injury	Time to Hospital (min)	Initial Hemodynamic Status	PACU/ICU Interventions	ICU Stay (days)	Early Complications
28	Male	7	Motor Vehicle Accident	20	Stable	Airway Management, ICP Monitoring, Fluids	10	Elevated ICP, Seizure
45	Female	5	Fall from Height	35	Unstable	Mechanical Ventilation, ICP Monitoring, Vasopressors	18	Hypotension, Hematoma
62	Male	9	Assault	50	Stable	Fluids, Pain Management, ICP Monitoring	7	Mild Cognitive Impairment
33	Female	6	Motorcycle Crash	25	Unstable	Mechanical Ventilation, Sedation, ICP Monitoring	15	ARDS, Elevated ICP
50	Male	8	Fall from Stairs	40	Stable	Fluids, ICP Monitoring, Early Rehab	12	Hemorrhage, Delirium

The table (2), presents hypothetical data for five traumatic brain injury (TBI) patients admitted immediately to the PACU or ICU. Patients range from 28 to 62 years old, with a mix of genders, illustrating that TBI can occur across a wide adult age spectrum. The Glasgow Coma Scale (GCS) on arrival ranges from 5 to 9, representing moderate to severe TBI and highlighting the need for urgent neurological assessment and intervention.

The mechanism of injury varies, including motor vehicle accidents, falls, assaults, and motorcycle crashes, reflecting the diverse etiologies of TBI. Time to hospital ranges from 20 to 50 minutes, emphasizing the importance of rapid prehospital transport for minimizing secondary brain injury. Initial hemodynamic status shows that some patients were stable while others were unstable, directly influencing ICU interventions and expected outcomes.

PACU/ICU interventions include airway management, mechanical ventilation, intracranial pressure (ICP) monitoring, fluids, vasopressors, and early rehabilitation. Patients with unstable vital signs generally required more aggressive interventions, such as mechanical ventilation and vasopressor support, indicating a higher risk of secondary complications.

Early complications include elevated ICP, seizures, hemorrhage, acute respiratory distress syndrome (ARDS), hypotension, delirium, and mild cognitive impairment. These complications highlight the high vulnerability of TBI patients to both neurological and systemic issues. Finally, ICU length of stay correlates with both initial GCS and hemodynamic stability. Patients with lower GCS and unstable vitals tended to have longer ICU stays. This data emphasizes that rapid neurological assessment, hemodynamic stabilization, ICP management, and early intervention in PACU/ICU are essential to reduce morbidity and improve outcomes in TBI patients.

Special Scenario: Patients with Both Major Burns and TBI

- ✓ **Airway/ventilation:** Treat as inhalation injury risk and neuro-protective ventilation: avoid hypoxia/hypercapnia; cautious PEEP to balance oxygenation and venous return (affects ICP).
- ✓ **Fluids:** Burn resuscitation can worsen cerebral edema; use dynamic hemodynamic assessment (UO, lactate, echo-guided fluid responsiveness). Consider early vasopressors to meet CPP rather than excessive crystalloids.
- ✓ **Sedation/analgesia:** Favor agents with predictable neuro-hemodynamic profiles (propofol/opioid ± ketamine).
- ✓ **Positioning:** Head-of-bed 30°, but protect grafts and donor sites; manage cervical precautions if polytrauma.

Table 3. Patients with Both Major Burns and TBI (Immediate PACU/ICU)

Age (years)	Gender	TBSA (%)	Burn Type	GCS on Arrival	Mechanism of Injury	Time to Hospital (min)	Initial Hemodynamic Status	PACU/ICU Interventions	ICU Stay (days)	Early Complications
35	Male	50%	Thermal	6	Motor Vehicle + Fire	30	Unstable	Fluids, Mechanical Ventilation, ICP Monitoring, Pain Management	25	Elevated ICP, Hypovolemic Shock, Infection
28	Female	60%	Chemical	5	Industrial Accident	45	Unstable	Aggressive Fluid Resuscitation, Sedation, ICP Monitoring, Antibiotics	30	ARDS, Hemorrhage, Sepsis
42	Male	40%	Thermal	7	Fall + Fire	50	Stable	Fluids, Pain Management, ICP Monitoring, Wound Care	20	Elevated ICP, Local Infection
19	Female	70%	Electrical	4	Electric Shock + Motor Vehicle	25	Unstable	Mechanical Ventilation, ICP Monitoring, Fluids, Pain Control	35	Shock, ARDS, Multi-organ Dysfunction
50	Male	55%	Thermal	8	Motor Vehicle + Burn	40	Stable	Fluids, ICP Monitoring, Early Rehab, Wound Management	22	Hemorrhage, Delirium

Patients with both major burns and traumatic brain injury (TBI) represent one of the most challenging scenarios in critical care. In this hypothetical cohort, patients range from 19 to 50 years old, with both males and females affected. TBSA burned is extensive, ranging from 40% to 70%, indicating a significant risk of hypovolemia, infection, and metabolic instability. GCS on arrival varies from 4 to 8, reflecting moderate to severe TBI. The combination of low GCS and extensive burns creates a dual threat to both neurological and systemic stability. Mechanisms of injury include motor vehicle accidents, industrial incidents, falls, and electrical injuries combined with fire or trauma, illustrating the complexity of polytrauma in these patients. Time to hospital ranges from 25 to 50 minutes, highlighting the critical role of rapid prehospital care and triage in reducing secondary injury. Initial hemodynamic status shows that most patients were unstable, necessitating aggressive interventions to maintain perfusion and oxygenation. PACU/ICU interventions are multifaceted, including fluid resuscitation, mechanical ventilation, intracranial pressure (ICP) monitoring, pain control, sedation, wound care, antibiotics, and early rehabilitation. The need for simultaneous management of brain injury and extensive burns increases the complexity of care and resource utilization. Early complications in this cohort are severe and often multi-systemic, including elevated ICP, hypovolemic shock, ARDS, sepsis, hemorrhage, delirium, and multi-organ dysfunction. ICU length of stay is prolonged, ranging from 20 to 35 days, and generally correlates with the severity of both TBSA burned and GCS score. This scenario underscores that early recognition, aggressive resuscitation, meticulous ICP monitoring, infection prevention, and coordinated multi-system care are critical to improving outcomes. The dual burden of major burns and TBI significantly increases morbidity, mortality, and the complexity of ICU management.

Discussion

- ✓ **Evidence consistency:** High-quality, consensus-driven guidelines exist for severe TBI (BTF 4th edition; 2020 decompressive update) and for key aspects of burn care (ABA fluid resuscitation 2023; ABA rehab CPG). These provide strong targets for hemodynamics, ventilation, and timing of interventions. Areas with evolving or heterogeneous evidence include: optimal sedative choice/combination in TBI; comparative effectiveness of HTS vs mannitol; colloid timing in burns; and standardized protocols for inhalation injury adjuvants [23].
- ✓ **Post-anesthesia specifics:** Emergence/extubation decisions in burns hinge on evolving airway edema and repeated returns to OR; in TBI, they hinge on neuro-exam reliability and ICP stability. Pain is undertreated in burns regional techniques and ketamine can reduce opioid load and facilitate early

mobilization [24]. In TBI, intermittent sedation holds for neurologic assessment improve decision-making but must not trigger ICP spikes; dexmedetomidine can help with arousable exams at the cost of bradycardia/hypotension risk [25-27].

- ✓ **Protocols & systems:** Embedding checklists and escalation bundles (for ICP crises, for post-burn fluid creep, for dressing-change analgesia) reduces variability [28-30]. Recent ACS best-practice guidelines for TBI add pragmatic content on imaging cadence, biomarkers, pharmacologic strategies, and post-acute systems of care that can be adapted to anesthesia-ICU handoffs [31].
- ✓ **Limitations:** The TBI evidence base includes relatively few Class I trials; burn literature is heterogeneous with many observational or physiologic endpoints [32-34]. Many recommendations are conditional or context-dependent; resource settings (e.g., access to ICP monitoring, advanced ventilators, regional anesthesia expertise) influence implementation [35].

Key Post-Anesthesia Order Set (Adult, to adapt locally)

- ✓ **Airway/ventilation:** ETT secured; Vt ~6 mL/kg PBW; PEEP per ARDS-lung profile; ABG in 30–60 min; PaO_2 80-150, $PaCO_2$ 35-40 [36].
- ✓ **Hemodynamics:** MAP/CPP goals; norepinephrine first-line if CPP low despite fluids.
- ✓ **Fluids:** Balanced crystalloids; in burns, titrate to UO 0.5-1 mL/kg/h and lactate; assess for "fluid creep."
- ✓ **Analgesia/sedation:** Fentanyl/remifentanil + propofol; adjunct ketamine (0.1-0.3 mg/kg/h) and acetaminophen; consider dexmedetomidine for arousable exams; daily sedation plan [37].
- ✓ **Neuro:** HOB 30°; Na^+, osmolality q6-8 h if on hyperosmolar therapy; seizure prophylaxis plan; CT timing.
- ✓ **Prophylaxis & bundles:** LMWH timing (per neurosurgery if TBI), ulcer prophylaxis, glucose protocol, temperature management, early enteral feeds, line care, daily mobilization goals [38].

Future Directions

- ✓ Pragmatic trials comparing sedation bundles (propofol-opioid vs propofol-dexmedetomidine vs ketamine-forward) on neurologic outcomes and ICU LOS in TBI [39].
- ✓ Standardized pathways for combined burn-TBI injuries (balancing CPP and anti-edema strategies with burn resuscitation) [40].
- ✓ Wider adoption and trials of regional anesthesia in burn care, including continuous peripheral nerve catheters for donor sites.

Discussion

The findings of this systematic review provide an integrated perspective on the unique clinical considerations involved in managing patients with burns and traumatic brain injuries (TBI) after anesthesia [41]. These two patient groups, though distinct in etiology, share overlapping vulnerabilities that require tailored perioperative and postoperative strategies. Burn patients often experience extensive fluid and electrolyte imbalance, compromised immune responses, and altered pharmacokinetics of anesthetic drugs, while TBI patients suffer from disrupted cerebral autoregulation, elevated intracranial pressure (ICP), and high susceptibility to secondary neurological injuries [42]. When anesthesia is administered, these vulnerabilities become more pronounced, necessitating an evidence-based approach to optimize outcomes.

1- Hemodynamic Management and Fluid Therapy:

One of the central themes across reviewed studies is the challenge of hemodynamic stability. Burn patients typically require aggressive fluid resuscitation in the acute phase, yet excessive resuscitation can lead to complications such as abdominal compartment syndrome and pulmonary edema [5]. For TBI patients, overzealous fluid administration can exacerbate cerebral edema and worsen outcomes. Anesthesia compounds this challenge by causing vasodilation and myocardial depression, necessitating precise titration of fluids and vasoactive agents. Evidence suggests that goal-directed fluid therapy, guided by invasive monitoring such as central venous pressure or stroke volume variation, significantly reduces complications in both patient populations [6].

Additionally, the type of fluid plays a critical role. Crystalloids remain first-line in burn resuscitation, but their use in TBI patients raises concerns about dilutional hyponatremia and increased cerebral swelling. Hypertonic saline has been shown to provide dual benefits by reducing ICP while supporting intravascular volume, suggesting it may be an appropriate fluid of choice when both burns and TBI coexist [4].

2- Airway and Respiratory Considerations:

Airway management is particularly complex in burn patients, especially those with inhalation injuries or upper airway edema. The literature highlights the need for early intubation before edema becomes unmanageable. In TBI patients, the major concern is maintaining adequate oxygenation and normocapnia to prevent secondary brain injury. Anesthetic induction agents can exacerbate hypoventilation or

alter cerebral perfusion pressure (CPP), making careful drug selection imperative.

Studies emphasize that mechanical ventilation strategies must balance oxygen delivery with the risk of ventilator-induced lung injury. Burn patients often develop acute respiratory distress syndrome (ARDS), while TBI patients require tight control of $PaCO_2$ to maintain stable ICP. Low tidal volume ventilation, coupled with permissive hypercapnia in burns, contrasts with the strict avoidance of hypercapnia in TBI, underscoring the nuanced balance clinicians must achieve.

3- Anesthetic Drug Selection and Pharmacological Challenges:

Drug pharmacokinetics and dynamics are profoundly altered in both populations. In burn patients, hypoalbuminemia, increased capillary permeability, and altered hepatic metabolism accelerate the clearance of many anesthetic agents, necessitating higher doses for therapeutic effect. Conversely, TBI patients are vulnerable to the cerebral depressant effects of anesthetics that may worsen ICP or reduce CPP [41].

Propofol, a common induction agent, provides neuroprotection through ICP reduction but carries the risk of hypotension, which can be detrimental to burn patients requiring hemodynamic stability. Ketamine, previously avoided in TBI due to concerns about ICP elevation, is now increasingly supported by recent evidence as safe and effective, particularly in patients with hypotension or hypovolemia. Opioids remain cornerstone agents for analgesia, though tolerance in burn patients and risk of respiratory depression in TBI necessitate multimodal analgesia approaches, incorporating regional blocks and non-opioid adjuncts.

4- Infection Control and Immune Modulation:

Infection is a leading cause of morbidity in burn patients, whereas TBI patients are susceptible to pneumonia and sepsis secondary to prolonged intubation and ICU stays. The immunosuppressive effects of anesthesia further exacerbate infection risks in both groups. The review highlights the importance of perioperative antibiotic prophylaxis, strict aseptic techniques, and novel immune-modulating therapies such as immunonutrition.

Burn patients often exhibit a hyper metabolic and hyper inflammatory response, complicating immune management. Conversely, TBI triggers systemic immunodepression via the "brain–immune axis." These differences underscore the importance of individualized immune-supportive strategies rather than a uniform approach.

5- Neurological Monitoring and Cerebral Protection:

For TBI patients, neurological monitoring is central to perioperative care. ICP monitoring, brain tissue oxygenation, and cerebral perfusion assessments are critical to prevent secondary injuries. Burn patients with concomitant TBI present additional complexity, as systemic instability and hypoxia from burns can exacerbate cerebral injury. The integration of multimodal monitoring such as jugular venous oximetry, near-infrared spectroscopy, and continuous EEG has been shown to improve detection of deleterious cerebral events. Therapeutic hypothermia and neuroprotective anesthetic regimens are explored in the literature, though their application remains controversial. While hypothermia may provide neuroprotection in TBI, it increases infection risks in burn patients, necessitating a balanced evaluation of risks and benefits.

6- Postoperative Pain and Rehabilitation:

Effective pain control is essential for both populations but poses unique challenges. Burn patients require high analgesic doses due to central sensitization and opioid tolerance, while TBI patients are at risk of over sedation, which may obscure neurological assessments. Multimodal analgesia, including acetaminophen, gabapentinoids, NMDA receptor antagonists, and regional anesthesia, is increasingly supported. Early rehabilitation strategies such as physical therapy, occupational therapy, and cognitive interventions are highlighted in the literature as vital for long-term functional recovery.

7- Ethical and Resource Considerations:

The management of these patients also involves ethical dilemmas and resource allocation challenges, especially in mass casualty settings or limited-resource environments. Burn patients with extensive injuries and TBI patients with severe neurological impairment often face poor prognoses, raising questions about the balance between aggressive interventions and palliative care. Several reviewed studies call for interdisciplinary decision-making, integrating perspectives from surgery, neurology, anesthesiology, critical care, and ethics.

8- Future Directions and Research Gaps:

This review reveals several gaps in current evidence. First, there is limited research on patients with combined burns and TBI, despite the frequent coexistence of these injuries in trauma settings. Second, there is a lack of randomized controlled trials comparing anesthetic agents in these populations, making it difficult to establish clear drug preference guidelines. Third, integration of personalized medicine approaches such as genetic profiling and individualized pharmacokinetics remains in early stages. Finally, long-term outcomes, particularly quality of life, cognitive function, and psychosocial reintegration, are underexplored. The management of burn and TBI

patients after anesthesia requires a multidimensional, evidence-based approach that addresses hemodynamic stability, airway protection, drug pharmacokinetics, infection control, and neurological monitoring. Despite advances, significant challenges remain, particularly in tailoring therapy to patients with combined injuries. Interdisciplinary collaboration and future research focusing on integrated protocols, novel pharmacological strategies, and long-term rehabilitation outcomes are essential to improve survival and quality of life for these highly vulnerable populations [42].

Conclusion

The systematic review of medical and therapeutic measures for patients with burns and traumatic brain injuries (TBI) following anesthesia highlights the complexity of perioperative and postoperative care for these highly vulnerable populations. Both burns and TBI present unique pathophysiological alterations that complicate anesthetic management and influence clinical outcomes. When anesthesia is administered, the physiological stress and potential secondary insults can significantly affect the healing trajectory and recovery potential of such patients. This review underscores the importance of multidisciplinary interventions, precise anesthetic selection, and careful postoperative monitoring to mitigate adverse effects. For burn patients, the challenges of fluid imbalance, immune dysregulation, hyper metabolism, and increased infection risk demand tailored anesthetic and therapeutic strategies. Anesthesia can exacerbate hemodynamic instability if fluid management is not properly calibrated. Evidence suggests that early and continuous monitoring of cardiovascular function, renal perfusion, and tissue oxygenation is essential in optimizing perioperative stability. Moreover, therapeutic measures such as advanced wound management techniques, nutritional optimization, and infection control are vital to enhancing recovery and minimizing long-term complications.

In the case of TBI patients, anesthetic management must address the delicate balance between preventing secondary brain injury and maintaining systemic homeostasis. Factors such as intracranial pressure (ICP), cerebral perfusion pressure (CPP), and oxygenation require continuous surveillance. The choice of anesthetic agents particularly their effects on cerebral metabolism and hemodynamics plays a pivotal role in patient outcomes. For example, volatile anesthetics may increase cerebral blood flow and ICP, whereas intravenous agents like propofol and ketamine offer more favorable neuroprotective profiles. Therapeutic interventions such as controlled ventilation, hyperosmolar therapy, and neuroprotective pharmacologic agents further contribute to improved outcomes. A recurring theme in this review is the necessity of individualized, patient-centered care. Neither burn injury nor TBI represents a uniform clinical presentation; instead, each patient exhibits distinct physiological and psychological needs shaped by injury severity, comorbidities, and anesthetic exposure. Thus, standardized protocols must be adaptable to context-specific challenges. The literature strongly advocates for a multidisciplinary approach involving anesthesiologists, surgeons, intensivists, neurologists, and rehabilitation specialists to ensure integrated management strategies. Another critical consideration is the role of rehabilitation and long-term recovery measures. While acute management of burns and TBI after anesthesia is life-saving, the trajectory of recovery depends heavily on rehabilitative interventions that address cognitive, motor, and psychosocial outcomes. Rehabilitation medicine, physical therapy, and psychological support are integral to reducing disability and enhancing quality of life. In addition, the application of novel technologies such as advanced monitoring systems, regenerative medicine, and artificial intelligence-assisted protocols shows promise in improving long-term outcomes. Overall, this systematic review demonstrates that effective management of burns and TBI after anesthesia requires vigilance, precision, and integration across multiple domains of care. Preventing complications such as infection, hypo perfusion, cerebral ischemia, and prolonged metabolic stress is as important as treating the primary injury. The review also emphasizes the importance of continuous education and training for healthcare professionals to remain updated with evolving evidence-based practices. In conclusion, the clinical considerations for patients with burns and TBI after anesthesia reveal the urgency of multidisciplinary and evidence-based care strategies. The alignment of medical, anesthetic, and therapeutic interventions significantly influences survival, functional recovery, and quality of life. Future research should focus on developing more targeted anesthetic protocols, exploring novel therapeutic agents, and expanding the evidence base through high-quality clinical trials. By integrating personalized care, advanced monitoring, and innovative technologies, clinicians can optimize outcomes and reduce the long-term burden associated with these devastating injuries

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