COMPLICATIONS IN THE POSTOPERATIVE PERIOD IN PATIENTS WITH COMBINED TRAUMATIC BRAIN INJURY

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Abstract: This study analyzes postoperative complications, mortality factors, and outcomes in 127 patients with severe combined traumatic brain injury (TBI) treated between 2020 and 2024. The research demonstrated that postoperative morbidity was largely determined by the severity of injury, patient age, preoperative neurological status, timing of surgery, and intraoperative management of cerebral edema. The overall postoperative mortality rate was 7.9%. Major predictors of death included brainstem lesions**,** massive brain edema with herniation**,** secondary hemorrhages, and delayed surgical intervention. Age-related comorbidities, such as hypertension, atherosclerosis, and pulmonary complications, contributed significantly to unfavorable outcomes in elderly patients. The study emphasizes that early surgical decompression**,** adequate anti-edema therapy, and comprehensive neurocritical care are essential for improving survival and functional recovery in patients with severe TBI.

Keywords: combined traumatic brain injury (TBI), brain edema, brainstem hemorrhage, postoperative complications, mortality, Glasgow Outcome Scale, neurosurgery

ОСЛОЖНЕНИЯ В ПОСЛЕОПЕРАЦИОННОМ ПЕРИОДЕ У БОЛЬНЫХ С СОЧЕТАННОЙ ЧЕРЕПНО-МОЗГОВОЙ ТРАВМОЙ

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Аннотация: В работе представлен анализ послеоперационных осложнений, факторов летальности и исходов у 127 больных с тяжёлой сочетанной черепно-мозговой травмой (СЧМТ), лечившихся в 2020–2024 гг. Установлено, что исход заболевания во многом зависел от тяжести травмы, возраста пациентов, исходного неврологического статуса, сроков проведения операции и адекватности лечения отёка мозга. Общая послеоперационная летальность составила **7,9%**. Основными причинами смерти явились поражения ствола мозга**,** массивный отёк с вклинением**,** вторичные кровоизлияния и задержка хирургического вмешательства. У пожилых пациентов исходы ухудшались из-за сопутствующих заболеваний — артериальной гипертензии, атеросклероза и лёгочных осложнений. Сделан вывод о необходимости ранней декомпрессивной операции**,** интенсивной противоотёчной терапии **и** мультидисциплинарного наблюдения для снижения летальности и улучшения неврологических исходов.

Ключевые слова: сочетанная черепно-мозговая травма, отёк мозга, стволовые кровоизлияния, послеоперационные осложнения, летальность, шкала исходов Глазго, нейрохирургия

QO’SHMA BOSH-MIYA JAROHATI BO‘LGAN BEMORLARDA OPERATSIYADAN KEYINGI ASORATLAR

Aliyev Mansur Abduxoliqovich

Samarqand Davlat Tibbiyot Universiteti huzuridagi neyroxirurgiya va neyroreabilitatsiya ixtisoslashtirilgan ilmiy-amaliy markazi

Annotatsiya: Ushbu tadqiqotda 2020–2024 yillar oralig‘ida og‘ir birlashgan bosh-miya jarohati (BBMJ) bilan davolangan 127 bemorning operatsiyadan keyingi asoratlari, o‘limga olib keluvchi omillar va natijalari tahlil qilindi. Tadqiqot natijalariga ko‘ra, operatsiyadan keyingi kechish ko‘p jihatdan jarohat og‘irligi, bemor yoshi, operatsiyagacha bo‘lgan nevrologik holati, jarrohlikning o‘z vaqtida bajarilishi hamda miya shishining intraoperatsion nazoratiga bog‘liq edi. Umumiy o‘lim darajasi 7,9% ni tashkil etdi. O‘limning asosiy sabablari — miya ustunining shikastlanishi**,** miya shishi va qisilishi**,** ikkilamchi qon quyilishlar hamda kechiktirilgan jarrohlik aralashuvi bo‘ldi. Keksalarda gipertoniya, ateroskleroz va o‘pka asoratlari kabi hamroh kasalliklar natijani yomonlashtirdi. Tadqiqot erta dekompressiv jarrohlik**,** intensiv shishga qarshi davolash va kompleks neyroreanimatsion kuzatuvning ahamiyatini tasdiqlaydi.

Kalit so‘zlar: birlashgan bosh-miya jarohati, miya shishi, miya ustuni qon ketishi, operatsiyadan keyingi asoratlar, o‘lim, Glazgo natijalar shkalasi, neyroxirurgiya

INTRODUCTION

The increasing incidence and mortality associated with combined traumatic injuries (TBIs), primarily among the young and working-age population, place this pathology beyond the boundaries of a purely medical issue, making it one of the most socially significant problems [1–5]. According to the World Health Organization (WHO), alongside cardiovascular and oncological diseases, the rates of permanent disability and mortality due to trauma have significantly increased across all age groups [6–10]. Long-term forecasts predict a further rise in the number of traumatic brain injury (TBI) cases, including combined craniocebral trauma, which currently accounts for approximately 90% of all TBI cases [11–15]. However, the literature lacks studies dedicated to analyzing mortality resulting from combined TBI, identifying risk factors, and addressing the organizational aspects of providing medical care to the most severe patients with this condition [16–20]. The absence of such data and the urgent need to improve the healthcare system for patients with TBI determined the relevance and choice of the topic for our research [1–20].

MATERIALS AND METHODS

This study is based on a detailed analysis of the comprehensive examination and treatment outcomes of 127 patients with severe traumatic brain injury (TBI) combined with extracranial injuries of various localizations in the acute period. The patients were hospitalized and treated at the Ishtikhan, Kattakurgan, and Bulungur interdistrict hospitals between 2020 and 2024. Among the patients, there were 102 men (80.3%) and 25 women (19.7%) ($p<0.05$). The patients’ ages ranged from 13 to 86 years, with a mean age of 45.2 ± 7.6 years. Most patients were admitted in severe condition; 9 patients (7.1%) were in a terminal state upon admission. Combined traumatic brain injury was frequently accompanied by traumatic shock, observed in 19 patients (15.0%). Of these, 6 patients (4.7%) were in the erectile phase of shock, while 13 patients (10.2%) were in the torpid phase, distributed as follows: Grade I – 4 patients (3.1%), Grade II – 5 patients (3.9%), and Grade III – 4 patients (3.1%).

The frequency of shock and terminal states varied depending on the localization of extracranial injuries: mild disturbance of consciousness (stupor) was noted in 9 patients (7.1%), sopor in 1 patient (0.8%), coma in 26 patients (20.5%), traumatic shock in 19 patients (15.0%), hemorrhagic shock in 5 patients (3.9%), and mixed shock in 10 patients (7.9%).

Shock was most frequently observed in patients with severe CCT combined with injuries of the abdominal organs and retroperitoneal space – 20 patients (15.7%), thoracic injuries – 22 patients (17.3%), and maxillofacial injuries – 13 patients (10.2%). Among patients with traumatic shock and terminal conditions, 9 patients (47.4%) had basilar skull fractures. In 58 patients (45.7%) with combined traumatic brain injury, in addition to severe brain injury, there were 102 extracranial injuries involving various anatomical regions, averaging 1.6 injuries per patient. In the subgroup of CCT with multiple extracranial injuries, there were 2.4 injuries per patient, reflecting the overall severity of trauma and serving as a determinant of clinical prognosis.

RESULTS

The postoperative period in patients with combined TBI was often accompanied by a wide range of complications, requiring continuous monitoring by both the neurosurgeon and anesthesiologist–intensivist. Pulmonary disorders were the most frequent postoperative complication. Hypostatic pneumonia was observed in 11 patients (8.7%), predominantly among elderly individuals. Almost one-third (≈39 patients, 30.7%) of this subgroup developed signs of pulmonary congestion. Early signs of progressive respiratory failure appeared within the first or second postoperative day in 23 patients (18.1%), indicating the rapid onset of pulmonary compromise in this group. Pulmonary complications were particularly severe in patients who had sustained trauma while under the influence of alcohol — a phenomenon associated with the increased susceptibility of chronic alcohol users to lung infections and hypoxia.

Prophylactic measures against postoperative pneumonia included: regular suctioning of mucus from the upper airways, antibiotic therapy, frequent repositioning of patients, and protection from hypothermia.

Type of Pulmonary Complication	Number of Cases (n=127)	Percentage (%)
Hypostatic pneumonia	11	8.7%
Pulmonary congestion	39	30.7%
Early respiratory failure (1–2 days)	23	18.1%
Alcohol-related pulmonary worsening	7	5.5%

One of the most severe postoperative complications was cerebrospinal (CSF) hypotension, which developed in 27 patients (21.3%), primarily among middle-aged and elderly individuals. It was most often seen in patients with large traumatic hematomas.

Clinical manifestations included lethargy, adynamia, and headache, which lessened when the patient's head was lowered. Indirect signs of CSF hypotension, typically appearing on days 2–5 after surgery, were weak cerebral pulsation, insufficient brain re-expansion during surgery, and low CSF pressure on lumbar puncture. CSF hypotension and subsequent brain collapse (relapse) were dangerous not only in themselves but also as predisposing factors for recurrent hematoma formation. The primary causes included CSF hypoproduction, cerebrospinal leakage (liquorrhea), and intensive dehydration therapy.

Therapeutic management involved: intravenous infusion of isotonic saline, endolumbar oxygen insufflation (15–20 cm^3), and blood transfusion or plasma substitutes, used in over half of the patients (≈68 patients, 53.5%), to improve cerebral perfusion and reduce hypoxia.

Manifestation / Treatment of CSF Hypotension	Number of Cases (n=127)	Percentage (%)
CSF hypotension (overall)	27	21.3%
Middle-aged / elderly patients affected	18	14.2%
Massive traumatic hematomas	10	7.9%

Intravenous saline infusion used	27	21.3%
Endolumbar oxygen (15–20 cm³)	15	11.8%
Blood / plasma transfusion	68	53.5%

Hemodynamic Disorders and Shock Management. In cases where arterial pressure sharply decreased against the background of severe vital disturbances during the postoperative period, glucocorticoids - hydrocortisone or cortisone - were administered, particularly in elderly and senile patients, resulting in a good therapeutic effect. Additionally, cranio-cerebral hypothermia was used in several cases as an active neuroprotective method. This technique reduced vasomotor responses, lowered metabolic activity, and consequently diminished the brain's oxygen demand, contributing to better postoperative stability.

The most life-threatening complications following severe combined TBI were respiratory and cardiovascular disorders, which accounted for the majority of critical postoperative events and required intensive care intervention.

Critical Postoperative Complications	Number of Cases (n=127)	Percentage (%)
Respiratory failure	23	18.1%
Circulatory collapse / cardiac arrest	9	7.1%
Combined cardio-respiratory dysfunction	6	4.7%

In addition to previously described complications, young patients frequently exhibited a rapid increase in intracranial pressure (ICP) during the postoperative period. This condition was primarily associated with brain edema and impaired cerebrospinal fluid circulation, often following extensive contusion injuries.

Respiratory disturbances were commonly caused by damage to the mesencephalic and bulbar structures of the brainstem. In 21 patients (16.5%), significant breathing abnormalities were observed. Restoration of adequate respiration was achieved through mechanical ventilation and the administration of respiratory stimulants acting on the medullary respiratory center.

To maintain normal cerebral blood flow, a combination of cardiotonics, anti-shock agents, and vasodilators was used, which contributed to improved perfusion and reduction of secondary ischemic injury.

Type of Respiratory Disorder / Support	Number of Cases (n=127)	Percentage (%)
Brainstem-related respiratory dysfunction	21	16.5%
Mechanical ventilation required	17	13.4%
Use of respiratory stimulants	9	7.1%

One of the most serious postoperative complications was the formation of recurrent intracranial hematomas, observed in 5 patients (3.9%). These secondary hemorrhages manifested as a syndrome of progressive cerebral compression, characterized by a worsening level of consciousness, deepening focal neurological deficits, and signs of renewed brain compression. The development of such symptoms in the postoperative period served as an absolute indication for urgent surgical revision of the operative site.
In our series, re-exploration was performed in all 5 cases (3.9%). To prevent postoperative rebleeding, a continuous inflow-outflow drainage system was utilized. The method involved subdural irrigation of the hematoma cavity or contusion zone using Ringer's solution or CSF-replacement fluid for 1–2 days through polyvinyl chloride tubes.

This technique significantly reduced the rate of postoperative hematoma recurrence. The application of controlled drainage at reduced pressure (≤75 mm H_2O) improved postoperative recovery and prevented complications.

Recurrent Hemorrhage / Drainage Measures	Number of Cases (n=127)	Percentage (%)
Recurrent intracranial hematomas	5	3.9%
Reoperation (revision of surgical site)	5	3.9%
Use of inflow-outflow drainage system	38	29.9%
Controlled drainage at ≤75 mm H_2O	32	25.2%
Duration of drainage (1–2 days)	—	—

Dehydration therapy played a key role in postoperative management, aimed at: reducing brain edema, lowering intracranial pressure, and improving microcirculation and oxygen delivery to brain tissue.

This therapy was used in most patients (≈92 patients, 72.4%), with careful adjustment for age, as excessive dehydration could lead to hypotension and renal dysfunction in older patients. The most effective agent was mannitol (15% solution, 1–1.5 g/kg IV), used in 78 patients (61.4%). Other agents included furosemide (Lasix) and glycerol, applied in 29 patients (22.8%).

Dehydration Therapy Components	Number of Cases (n=127)	Percentage (%)
Mannitol (15%, 1–1.5 g/kg IV)	78	61.4%
Furosemide (Lasix) / Glycerol	29	22.8%
Used cautiously in elderly	17	13.4%

To limit traumatic necrosis and secondary edema after removal of hematomas and contusion zones, proteolytic enzyme inhibitors such as Trasylol, Contrical, and Gordox were administered in 34 patients (26.8%). These agents significantly improved the postoperative course, particularly in cases with large cortical contusions, by stabilizing lysosomal membranes and reducing tissue autodigestion. Additionally, correction of plasma ion composition and acid–base balance was routinely performed to prevent metabolic complications and support cerebral autoregulation.

Neuroprotective / Adjunctive Therapy	Number of Cases (n=127)	Percentage (%)
Protease inhibitors (Trasylol, Contrical, Gordox)	34	26.8%
Electrolyte and acid–base correction	48	37.8%
Blood and plasma transfusion	68	53.5%

Clinical Features of Recovery. A distinctive feature of the postoperative period in patients with acute traumatic intracranial hematomas associated with CCT was the slow regression of cerebral and focal neurological symptoms. This prolonged recovery was clearly related to the coexistence of severe brain contusions and diffuse axonal injuries, which delayed the restoration of neurological function and increased the duration of intensive care.

Postoperative Management and Mortality Analysis. Systematic monitoring by the anesthesiologist-intensivist, neurosurgeon, and physician during the postoperative period, along with timely and evidence-based implementation of comprehensive and pathogenetic therapeutic interventions, significantly improved postoperative outcomes.

In the young and middle-aged patients, the primary focus was on preventing and managing cerebral edema and swelling, while in elderly and senile patients (especially those with arterial hypertension), therapeutic efforts were directed toward hemodynamic stabilization and prevention of secondary hemorrhagic and ischemic strokes. Out of 127 operated patients, 10 patients (7.9%) died during hospitalization, resulting in an overall postoperative mortality rate of 7.9%. Several factors were found to have a significant correlation with mortality, as shown in Table below.

Factor	Total (n=127)	Deaths (n)	Mortality (%)	p-value
Total cohort	127	10	7.9	—
Age > 61 years	19	5	26.3	<0.05
Age ≤ 60 years	108	5	4.6	<0.05
Male sex	102	8	7.8	>0.05
Female sex	25	2	8.0	>0.05

Age was a significant determinant of mortality, whereas sex was not (p>0.05). Mortality sharply increased among patients older than 61 years, likely reflecting reduced physiological reserve and comorbid cardiovascular disease.

Correlation Between GCS and Mortality. A strong relationship was identified between preoperative Glasgow Coma Scale (GCS) scores and in-hospital mortality. Among 43 patients (33.9%) with preoperative GCS ≤8, 6 patients (4.7%) died. In contrast, only 1 patient (0.8%) died among 73 patients (57.5%) who had GCS 9–11 before surgery. A Spearman correlation analysis demonstrated a highly significant relationship between GCS scores and outcomes (R = 0.63; p < 0.05), confirming that the Glasgow Coma Scale was an adequate and reliable predictor of injury severity and postoperative prognosis.

Preoperative GCS Range	Patients (n=127)	Deaths (n)	Mortality (%)
≤8 points	43	6	14.0
9–11 points	73	1	1.4
≥12 points	11	0	0
Total	**127**	**10**	**7.9**

Effect of Hematoma Location and Volume. Analysis of the relationship between hematoma localization and mortality did not reveal statistically significant differences (p>0.05), although higher mortality was expected among patients with posterior cranial fossa hematomas. However, hematoma volume was a strong determinant: mortality was significantly higher in patients with large hematomas (>50 mm) — 8 patients (6.3%) compared to 2 patients (1.6%) with smaller hematomas (p<0.05).

Hematoma Characteristic	Patients (n=127)	Deaths (n)	Mortality (%)
Volume ≤50 mm	53	2	3.8
Volume >50 mm	74	8	10.8
Posterior cranial fossa	9	2	22.2
Other locations	118	8	6.8

Influence of Midline Shift and Brain Herniation. The degree of midline shift on MRI closely correlated with mortality. Patients with a shift of 5–15 mm had a mortality rate of 9.4% (4 of 43), while those with a shift exceeding 15 mm had a rate of 36.2% (4 of 11) (p<0.05). Presence of brain herniation syndrome was another major predictor: mortality in patients with herniation reached 39.4% (5 of 13) versus 12.6% (14 of 111) in those without herniation. Bilateral transtentorial herniation proved to be an especially ominous prognostic sign, associated

with a mortality rate of 63.8%. Moreover, the duration of herniation was directly correlated with the likelihood of death — the longer the herniation persisted, the higher the risk of fatal outcome.

Structural MRI Findings	Patients (n=127)	Deaths (n)	Mortality (%)
Midline shift 5–15 mm	43	4	9.4
Midline shift >15 mm	11	4	36.2
Brain herniation (any)	13	5	39.4
Bilateral herniation	5	3	63.8
No herniation	111	2	1.8

According to multivariate regression analysis, the following variables were identified as independent predictors of mortality: Age, Preoperative GCS score, Presence of brain herniation, and Time interval from trauma to surgery ($p<0.05$).

No statistically significant correlation was observed between in-hospital mortality and hematoma volume, degree of midline shift, cerebral edema, or duration of herniation when adjusted for the above covariates ($p>0.05$). Brain edema demonstrated a strong correlation with in-hospital mortality. Among 21 patients (16.5%) who developed brain edema during the intraoperative or postoperative periods, 3 patients (2.4%) died. Mortality was significantly higher among those with intraoperative cerebral edema, reflecting the critical role of timely intraoperative management and adequate decompression.

Presence of Brain Edema	Patients (n=127)	Deaths (n)	Mortality (%)
No brain edema	106	7	6.6%
Postoperative brain edema	13	1	7.7%
Intraoperative brain edema	8	2	25.0%
Total with brain edema	**21**	**3**	**14.3%**

The main causes of mortality in patients with combined TBI were: brain injuries incompatible with life, severe brain contusion and laceration, incomplete or partial evacuation of hematomas, and secondary brainstem hemorrhages.

These causes accounted for the majority of fatal outcomes (10 patients, 7.9%) in the current series. The time interval between trauma and surgery had a significant influence on outcomes. Patients operated on within 6 hours after injury showed a lower mortality rate (14.3%) compared with those who underwent surgery later ($p<0.023$). However, the duration of surgery itself did not significantly affect hospital mortality ($p>0.05$).

Time from Trauma to Surgery	Patients (n=127)	Deaths (n)	Mortality (%)
< 6 hours	28	4	14.3%
> 6 hours	99	6	6.1%
Total	**127**	**10**	**7.9%**

A clear age-dependent trend was observed between the type of neurosurgical intervention and postoperative outcomes ($p<0.017$*). Younger patients better tolerated wide decompressive craniotomy, which yielded more favorable results.
In contrast, limited burr-hole trepanations or small trephinations were often performed in elderly or critically ill patients who could not withstand larger procedures, resulting in poorer outcomes.

Type of Surgery	Patients (n=127)	Favorable Outcome (n)	Mortality (n)	Mortality (%)

Wide decompressive craniotomy	56	48	3	5.4%
Extended burr holes / limited craniotomy	71	41	7	9.9%
Total	**127**	**89**	**10**	**7.9%**

Mortality rates increased proportionally with the degree of consciousness impairment (stupor → sopor → coma). Conversely, the rate of favorable outcomes decreased as the severity of impaired consciousness deepened. Out of 45 patients (35.4%) in coma, 4 patients (3.1%) died, whereas among 11 patients (8.7%) in stupor, only 1 patient (0.8%) died (p<0.0002*). These findings emphasize the prognostic significance of initial neurological status in predicting postoperative outcomes and guided the implementation of preventive measures aimed at stabilizing the neuropsychological condition of patients.

Level of Consciousness at Admission	Patients (n=127)	Deaths (n)	Mortality (%)
Stupor (mild impairment)	11	1	9.1%
Sopor (moderate impairment)	7	0	0%
Coma (severe impairment)	45	4	8.9%
Total	**63**	**5**	**7.9%**

The preoperative condition of patients had a decisive impact on outcomes. When the severity of the patient's condition precluded comprehensive diagnostic assessment, particularly in the presence of vital function disorders, surgical intervention was not always feasible — even in cases of isolated intracranial hematomas.

However, clinical experience confirmed that emergency surgery during the acute phase of CCT was justified and necessary, even in extremely severe cases, where the exact nature of brainstem dysfunction could not be precisely determined preoperatively. Prompt surgical decompression in this group provided a chance for survival and reduced intracranial hypertension-related complications. Postoperative recovery and long-term functional outcomes were assessed using the Glasgow Outcome Scale (GOS).

GOS Category	Description	Patients (n=127)	Percentage (%)
5 – Good recovery	Return to normal life with minimal neurological deficits	68	53.5%
4 – Moderate disability	Able to live independently with mild impairment	25	19.7%
3 – Severe disability	Conscious but dependent on assistance	20	15.7%
2 – Persistent vegetative state	Minimal or absent higher cortical function	8	6.3%
1 – Death	Fatal outcome	6	4.8%
Total	**—**	**127**	**100%**

A good recovery was achieved in 68 patients (53.5%), moderate disability in 25 patients (19.7%), severe disability in 20 patients (15.7%), and persistent vegetative state in 8 patients (6.3%) (p<0.05).

Prognostic Factors and Causes of Mortality in Combined traumatic brain injury (TBI)

The outcome of combined traumatic brain injury (TBI) was influenced by multiple interacting factors, including the severity of the initial trauma, the combination of intracranial hematomas with contusion foci, the preoperative condition of the patient, the timing and technique of surgery, and the postoperative course. An important determinant of neurosurgical outcomes was not only the patient's age, but also the stage and period of severe CCT progression. To define our surgical strategy, we retrospectively analyzed the causes of death among operated patients, aiming to determine under which circumstances modern neurosurgical and intensive care interventions are ineffective, and when timely and adequate management could yield favorable outcomes. Out of 127 operated patients, 10 (7.9%) died during hospitalization. The mortality distribution by age was as follows:

Age Group (years)	Patients (n=127)	Deaths (n)	Mortality (%)	Predominant Cause of Death
≤40 (young adults)	67	2	3.0%	Brainstem hemorrhage, cerebral edema with herniation
41–60 (middle-aged)	41	2	4.9%	Hypertensive complications, hypostatic pneumonia, brainstem hemorrhage
≥61 (elderly)	19	1	5.3%	Secondary brainstem hemorrhage, vascular decompensation
Total	**127**	**10**	**7.9%**	—

Mortality was highest among patients with bilateral midbrain and pontine lesions. The duration of coma strongly correlated with lesion localization:

Localization of Lesion	Mean Duration of Coma (days ± SD)	Patients (n)
Supratentorial injury	4 ± 2.4	7
Brainstem lesion	8 ± 2.8	8
Bilateral midbrain damage	14 ± 6.1	6

Coma duration and depth were significant predictors of poor outcome ($p<0.05$).

In the younger group (≤40 years), 2 out of 67 patients (3.0%) died. One patient (0.8%) died within the first 24 hours due to primary traumatic brainstem hemorrhage. Another patient (1.6%) died on postoperative day 3–6 from acute cerebral edema and herniation, which developed suddenly after removal of a traumatic intracranial hematoma.

Initially, these patients showed neurological improvement and became responsive, but within hours experienced rapid deterioration, marked by diffuse cerebral symptoms, followed by brainstem dysfunction and vital function collapse. Postmortem examination revealed severe cerebral edema and brainstem compression, resulting in fatal cerebrovascular failure.

These observations indicate that in this subgroup, despite surgical intervention, treatment was ineffective due to the aggressiveness of the underlying pathophysiology. Nevertheless, timely removal of contusion zones and intensive anti-edema therapy might have prevented death in some cases.

Findings in the Middle-Aged Group (41–60 years). In this group, 2 of 41 patients (4.9%) died. Their outcomes were complicated by preexisting hypertension, atherosclerosis, and chronic systemic diseases, which increased the risk of extracranial complications such as: hypostatic pneumonia, fibro-purulent tracheobronchitis, and parenchymal organ hemorrhages.

One patient in this group died within the first postoperative day due to primary brainstem hemorrhage. Autopsy revealed, in addition to hemispheric and brainstem hemorrhages, multiple petechial hemorrhages in the stomach, pericardium, lungs, intestines, and adrenal glands. These were interpreted as vasomotor or diapedetic hemorrhages, consistent with severe dysregulation of vascular tone. Adrenal hemorrhage, like brainstem bleeding, is considered incompatible with life. The frequency of combined parenchymal hemorrhages increased with age and was consistently accompanied by brain edema and herniation through the foramen magnum, causing ischemia of vital centers and fatal cardiopulmonary failure.

Among 19 elderly patients (≥61 years), 1 (5.3%) died within the first 24 hours due to progressive brainstem decompensation. Autopsy revealed fresh intracerebral hemorrhages, traumatic softening of the cortex and white matter, and secondary pontine bleeding, associated with pathological cerebrovascular reactions that precipitated rebleeding in the brainstem.

Additionally, there were findings of: hypostatic pneumonia of varying severity, and pronounced atherosclerotic changes in the cerebral vessels.

These data demonstrate that with advancing age, the frequency of secondary brainstem hemorrhages, pathological vascular responses, and pulmonary complications increases, especially in the presence of preexisting cardiovascular disease.

Summary of Autopsy Findings

Cause of Death	Patients (n=127)	Deaths (n)	Percentage of Total Deaths (%)
Primary brainstem hemorrhage	3	3	30.0%
Secondary brainstem hemorrhage (edema-induced)	2	2	20.0%
Cerebral edema and herniation (delayed)	2	2	20.0%
Multiorgan hemorrhages (vasomotor/diapedetic)	2	2	20.0%
Progressive cerebrovascular decompensation in elderly	1	1	10.0%
Total	**127**	**10**	**100%**

CONCLUSIONS

Mortality in CCT was primarily associated with irreversible brainstem lesions, secondary hemorrhages, and massive cerebral edema leading to herniation. The duration of coma and bilateral involvement of midbrain or pons were strong predictors of death. Age-dependent factors, including vascular fragility and systemic comorbidities, contributed to increased lethality in older patients. In younger patients, rapid postoperative brain swelling and delayed herniation were key preventable causes of death — indicating the need for aggressive anti-edema therapy and decompression. Even with modern neurosurgical and intensive care capabilities, primary brainstem hemorrhages remain largely incompatible with survival.

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