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# Frailty Is Associated With Decreased Survival in Adult Patients With Nonoperative and Operative Traumatic Subdural Hemorrhage

## *A Retrospective Cohort Study of 381,754 Patients*

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**Objective:** We investigated frailty's impact on traumatic subdural hematoma (tSDH), examining its relationship with major complications, length of hospital stay (LOS), mortality, high level of care discharges, and survival probabilities following nonoperative and operative management.

**Background:** Despite its frequency as a neurosurgical emergency, frailty's impact on tSDH remains underexplored. Frailty characterized by multisystem impairments significantly predicts poor outcomes, necessitating further investigation.

**Methods:** A retrospective study examining tSDH patients ≥18 years and assigned an abbreviated injury scale score ≥3, and entered into ACS-TQIP between 2007 and 2020. We employed multivariable analyses for risk-adjusted associations of frailty and our outcomes, and Kaplan-Meier plots for survival probability.

**Results:** Overall, 381,754 tSDH patients were identified by mFI-5 as robust—39.8%, normal—32.5%, frail—20.5%, and very frail—7.2%. There were 340,096 nonoperative and 41,658 operative patients. The median age was 70.0 (54.0–81.0) nonoperative, and 71.0 (57.0–80.0) operative cohorts. Cohorts were predominately male and White. Multivariable analyses showed a stepwise relationship with all outcomes $P<0.001$; 7.1% nonoperative and 14.9% operative patients had an 20% to 46% increased risk of mortality, that is, nonoperative: very frail (HR: 1.20 [95% CI: 1.13–1.26]), and operative: very frail (HR: 1.46 [95% CI: 1.38–1.55]). There were precipitous reductions in survival probability across mFI-5 strata.

**Conclusion:** Frailty was associated with major complications, LOS, mortality, and high level care discharges in a nationwide population of 381,754 patients. While timely surgery may be required for patients with tSDH, rapid deployment of point-of-care risk assessment for frailty creates an opportunity to equip physicians in allocating resources more precisely, possibly leading to better outcomes.

**Keywords:** frailty, modified frailty index-5, mortality, risk assessment, traumatic subdural hemorrhage

Traumatic subdural hemorrhage (tSDH) is common in traumatic brain injury (TBI) and can be one of the most severe types of neurosurgical emergencies that carries a significant risk of permanent disability and mortality.[1–3] Mortality rates in this patient population ranges from 15% to 90%.[2–6] Several predictors of poor outcomes in patients with TBI have been identified, including advanced patient age, preexisting comorbidities, Glasgow Coma Scale (GCS), pupillary abnormalities, degree of midline shift, hematoma size, and, more recently, frailty.[3–10] Despite the pressing need for timely assessments and interventions in patients with tSDH to optimize outcomes, the existing body of literature offers limited insights into the effects of frailty on TBI outcomes. Therapeutic decisions regarding the futility of a nonoperative or operative management approach are frequently dependent on a surgeons' judgment and traditionally frailty has not been heavily considered in the decision-making process.[11]

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*This research was conducted in accordance with the ethical requirements of the institutional and/or national research committee and with the Helsinki Declaration of 1964 and any updates thereto or comparable ethical standards. The University of New Mexico's Institutional Review Board (IRB) has given its approval to this study, and the research was conducted following the rules laid out in the ACS-TQIP's data user agreement.*

*The authors declare that they have nothing to disclose.*

*The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting requirements were strictly adhered for this observational study.*

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In a wide range of medical and surgical disciplines, frailty has been shown to significantly predict poor outcomes.[12–20] Frailty, characterizing a patient's physiological resilience against stressors due to multisystem impairments, is a more important predictor of adverse health outcomes than the traditional measure of patient age alone.[13,21–24] Although many tools exist to augment the process of risk stratification, the 5-factor modified Frailty Index (mFI-5) has been validated in the trauma population.[25,26] Patients identified as frail or very frail have been shown to have worse outcomes compared with their nonfrail counterparts.[25,26] However, the paucity of evidence about the effects of frailty in tSDH patients may hinder our capacity to provide comprehensive care. Moreover, a deeper understanding of frailty in these patients may result in enhanced risk assessment during the initial encounter, therefore, paving the way for goal-oriented treatment strategies and collaborative decision-making.[27,28]

This study endeavors to highlight the impact of frailty on outcomes in tSDH, providing valuable insights that could guide future clinical decision-making. In our investigation, our study objectives are multifaceted, each aiming to elucidate the complex relationship between frailty and outcomes. Our initial objective centers on the distinction between nonoperative and operative tSDH patients. By stratifying our patient cohorts by frailty status, we highlight frailty's impact on these critical healthcare outcomes by treatment approach. Next, we aim to evaluate the impact of frailty on a range of outcomes in the nonoperative and operative cohorts. Our operative cohort examines the relationship between frailty and major postoperative complications. In both cohorts, other outcomes include length of hospital stay (LOS), mortality, and high level of care discharges. Our final objective focuses on survival probability across mFI-5 frailty risk strata, for both the nonoperative and operative cohorts. We hypothesize that there will be a stepwise dose-dependent relationship with increasing frailty and worse outcomes.

## METHODS

### *Study, Design, and Participants*

The American College of Surgeons Trauma Quality Improvement Program (ACS-TQIP)[29] is a large national database that developed from the National Trauma Data Base and permits benchmarking of trauma centers across risk-adjusted variables in the United States.[29] The committee on trauma of the American College of Surgeons maintains and compiles the National Trauma Data Base, which is publicly accessible.[30] Clinical data reviewers are trained and employed at contributing centers to ensure reliability of the aggregated data based on the highest trauma activation level. As of 2022, more than 875 participating trauma centers across North America contributed to the ACS-TQIP database. This observational study follows the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guidelines.[31] The University of New Mexico's Institutional Review Board did not consider our study as human subjects research. Nonetheless, our study meticulously adhered to the guidelines stipulated in the ACS-NSQIP data use agreement.

We designed a retrospective cohort study to examine clinical encounters of the ACS-TQIP database and specified a query for adult patients 18 years and older who sustained tSDH with an assigned abbreviated injury scale (AIS) score ≥3 (complemented by descriptive text), between January 1, 2007, and December 31, 2020. Patients were excluded if severe injuries other than an tSDH were present, if multicompartmental intracranial hemorrhages were present or if they had a nonsurvivable injury AIS 6 (Figure 1). The participant user files of the ACS-TQIP database includes clinically predefined variables, representing the demographic, clinical, and hospital characteristics for all encounters.

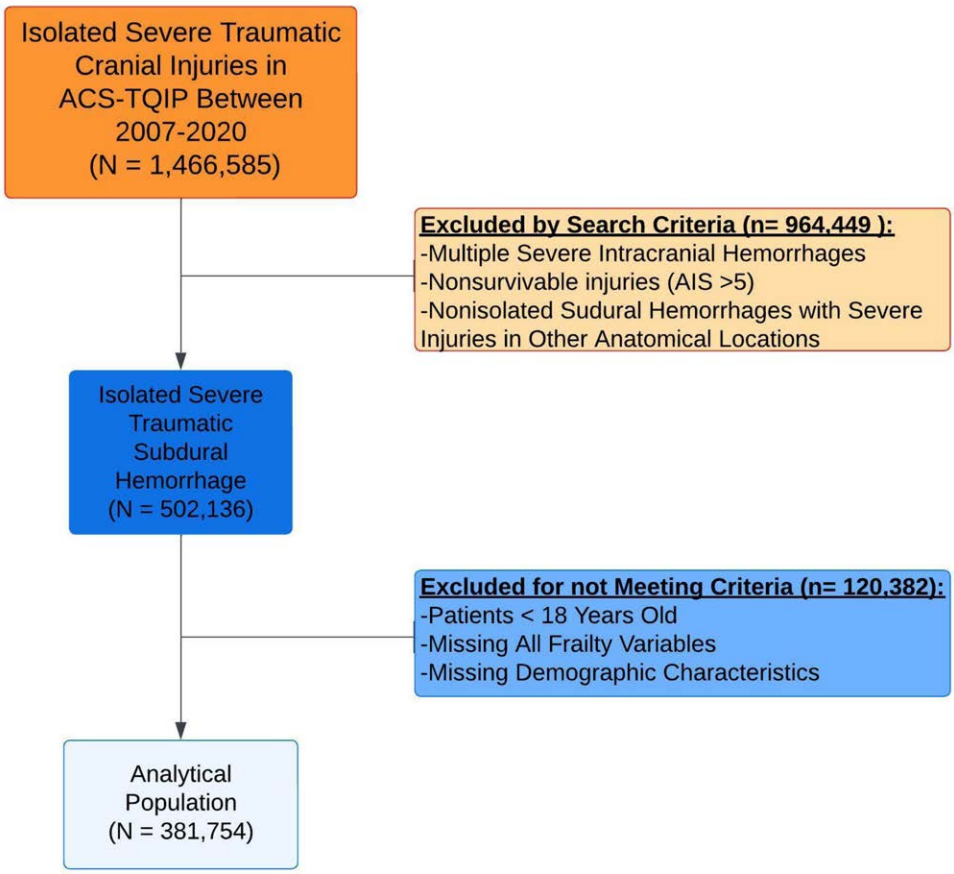


**FIGURE 1.** CONSORT flow diagram of adult acute traumatic subdural hemorrhage patients in the ACS-TQIP study (2007–2020).

There were only modest variations in reporting between the ICD-9 and ICD-10 transition years of 2014 to 2015.[30] We identified a tSDH patients that underwent corresponding craniotomy procedures based on previously published literature describing the coding methodology.[30] Time to craniotomy was calculated using the timestamps provided in the ACS-TQIP files. Stratification into nonoperative and operative cohorts enables us to control for the major difference in the two groups. This enables a more balanced comparison, as those with larger tSDH, lower GCS scores, and more severe neurological signs typically have poorer outcomes and are more likely to undergo surgery. Our aim is to minimize confounding variables and bias, by isolating the impact of frailty from the influence of surgical intervention. This approach also helps to offset the effect of secular trends, ensuring observed changes can be attributed to frailty rather than individual tSDH characteristics like size and patient GCS score, which we know significantly affect tSDH outcomes.

### *Modified Frailty Index-5*

The mFI-5 was used to categorize patients into frailty risk strata and takes into account four comorbidities and one functional independence assessment variable.[25,26] The comorbidity variables include congestive heart failure, diabetic requiring insulin/medication, chronic obstructive pulmonary disease, and medication-requiring hypertension. The mFI-5 has undergone extensive validation and its use in the ACS-TQIP database is well documented.[25,26] If a comorbidity is present, a score of "1" is assigned. When evaluating each patient, the sum of all five mFI-5 variables is tallied, with the highest attainable score of "5." Frailty risk strata are grouped into four broad categories: 0—robust, 1—normal, 2—frail, and ≥3—very frail.

### *Outcomes*

Major complications is defined by Clavien-Dindo severity categories III–IV.[32] Briefly, grade I complications are deviations from normal physiological status and necessitate treatments tailored to the patients' symptoms. Grade II severity requires medical intervention, including blood transfusions and total parenteral infusions. Grade III severity are occurrences that can be managed by radiologic, endoscopic, or surgical interventions. Finally, grade IV are life-threatening complications requiring intensive care unit management.[32] Total LOS is defined as counts of calendar days from initial encounter in the emergency department to discharge. Mortality includes deaths that occur during hospitalization (including withdrawal of care), and hospice for palliative care or the provision of comfort measures. High level of care discharges is defined as discharges to skilled care nursing facilities or other assisted living facilities because of the patient's inability to independently perform activities of daily living.

### *Statistical Analysis*

For the purpose of characterizing continuous data, medians and their corresponding interquartile ranges (IQR) were utilized. When characterizing dichotomous or categorical variables, frequency and percentage distributions were employed. Utilizing the Chi-square test, Fisher's exact test (for dichotomous or categorical data), and the nonparametric Mann-Whitney *U* test (for continuous data), unadjusted statistical comparisons were achieved. In our analyses, we found it necessary to exclude 2,347 (0.62%) patients, due to incomplete comorbidity information, which precluded accurate mFI-5 score computation. Additionally, 117 (0.03%) patients were excluded due to the absence of sex identifying codes (Figure 1).

Akaike information criterion was used to select the most parsimonious models. Additionally, clinical relevance was considered, ensuring that there were no collinear variables evident by a high variance inflation factor.[33] Age, sex, race, GCS, injury severity score (ISS), and AIS score were considered in the regression models. We employed a robust assortment of statistical methods to rigorously analyze our data. First, we used Generalized Estimating Equations time-series models,[34] a technique that recognizes the potential correlation within groups and the multiyear nature of our data. These models were implemented for both multivariable logistic and Poisson regressions. Second, utilizing semiparametric Cox models and nonparametric Kaplan-Meier analyses, we assessed HR and survival probabilities, respectively. The Cox models provides an understanding of multiple risks simultaneously. Kaplan-Meier analyses estimated survival probabilities over time, presenting a graphical view of patients' survival rates.

We applied multivariable logistic regression models to independently analyze the likelihood of major complications in the operative cohort, and high level care discharges for both cohorts. The results are reported as odds ratios (OR) and corresponding 95% confidence intervals (CI). Furthermore, we used multivariable Poisson regression to investigate the relationship with LOS, reporting incidence rate ratios (IRR), and their respective 95% CI. Finally, for mortality, we employed multivariable Cox regression, reporting hazard ratios (HR), and their 95% CI.

Kaplan-Meier plots analyzing survival data, and corresponding unadjusted HR and 95% CI are presented. We evaluated the predicted probabilities from Cox goodness-of-fit models, allowing us to compare observed and expected mortality frequencies across the various mFI-5 strata. We used a two-tailed significance test in our analyses, and a $P$ value ≤0.05 indicating statistically significant differences. All statistical analyses were performed using STATA 17 (StataCorp, LLP, College Station, TX).

## RESULTS

### *Study Population*

Tables 1 and 2 delineate the demographics, and the institutional, procedural, and clinical characteristics of our study population. Overall, we included 381,754 tSDH patients who were risk-assessed retrospectively using the mFI-5, and 151,859 (39.8%) were identified as robust, 124,225 (32.5%) as normal 78,189 (20.5%) as frail, and 27,481 (7.2%) as very frail. There were 340,096 nonoperative patients (Table 1), whereas 41,658 patients underwent surgical hematoma evacuation (Table 2).

### *Nonoperative tSDH Cohort*

The median age of nonoperative patients was 70.0 (IQR: 54.0, 81.0), the patients were predominately male 57.8% (196,597/340,096), and White 78.2% (265,926/340,096); only 8.4% (28,575/340,096) were of Hispanic ethnicity (Table 1). The most frequent cause of tSDH was blunt trauma 96.2% (327,246/340,096), other prominent traumatic injury characteristics included: AIS score IV 65.0% (220,923/340,096), and severe ISS (16–24) 65.0% (221,052/340,096), and a tSDH size of 0.6 to 1 cm 35.0% (119,126/340,096) (Table 1). Most patients received intensive care (ICU) 50.5% (171,699/340,096) and had a median ICU LOS of 2 days (IQR: 2.0, 3.0). Overall, the median LOS was 2.1 days (IQR: 0.4, 4.2), and the frail and very frail patients had longer LOS, 2.7 days (IQR: 0.5, 4.6) and 3.0 days (IQR: 0.5, 5.0), respectively, $P < 0.001$. The hospital complication rate was 9.4% (32,046/340,096), and patients were more often discharged home 59.9% (203,564/340,096). Nonetheless, frail 37.3% (25,883/69,388) and very frail 44.7% (11,102/24,833) patients were more likely to be discharged to a high level of care facility, $P < 0.001$. The overall mortality rate was 7.1% (24,282/340,096), and a stepwise rate increase was observed across mFI-5 risk strata, that is, frail 8.5%

**TABLE 1.**

**Demographics, Institutional, Procedural, and Clinical Characteristics of Nonoperative Acute Traumatic Subdural Hemorrhage Patients in ACS-TQIP from 2007 to 2020 (N = 340,096)**

| | Modified Frailty Index-5 | | | | | |
|---|---|---|---|---|---|---|
| | Nonoperative Traumatic Subdural Hemorrhage | | | | | |
| Variables | Total N = 340,096 | Robust N = 136,106 | Normal N = 109,769 | Frail N = 69,388 | Very Frail N = 24,833 | *P* |
| **Demographics** | | | | | | |
| Age, median (IQR), years | 70 (54, 81) | 54 (35, 72) | 75 (63, 82) | 76 (68, 83) | 77 (70, 83) | <0.001 |
| Sex, n (%) | | | | | | <0.001 |
| Male | 196,597 (57.8%) | 88,638 (65.1%) | 58,358 (53.2%) | 36,805 (53.0%) | 12,796 (51.5%) | |
| Female | 143,499 (42.2%) | 47,468 (34.9%) | 51,411 (46.8%) | 32,583 (47.0%) | 12,037 (48.5%) | |
| Race, n (%) | | | | | | <0.001 |
| White | 265,926 (78.2%) | 99,972 (73.5%) | 90,274 (82.2%) | 8 55,437 (79.9%) | 20,243 (81.5%) | |
| Black | 29,599 (8.7%) | 13,262 (9.7%) | 305 (7.6%) | 5781 (8.3%) | 2251 (9.1%) | |
| Asian | 9177 (2.7%) | 3413 (2.5%) | 2873 (2.6%) | 2245 (3.2%) | 646 (2.6%) | |
| Other* | 35,394 (10.4%) | 19,459 (14.3%) | 8317 (7.6%) | 5925 (8.5%) | 1693 (6.8%) | |
| Ethnicity, n (%) | 28,575 (8.4%) | 15,661 (11.5%) | 6354 (5.8%) | 5041 (7.3%) | 1519 (6.1%) | <0.001 |
| Hispanic | | | | | | |
| Vitals | | | | | | |
| Glasgow Coma Score ≥13, n (%) | 289,772 (85.2%) | 111,856 (82.2%) | 95,680 (87.2%) | 60,532 (87.2%) | 21,704 (87.4%) | <0.001 |
| Glasgow Coma Score 9–12, n (%) | 26,464 (7.8%) | 11,364 (8.3%) | 8028 (7.3%) | 5202 (7.5%) | 1870 (7.5%) | <0.001 |
| Glasgow Coma Score <8, n (%) | 23,860 (7.0%) | 12,886 (9.5%) | 6061 (5.5%) | 3654 (5.3%) | 1259 (5.1%) | <0.001 |
| Injury mechanism and characteristics | | | | | | |
| Injury mechanism, n (%) | | | | | | <0.001 |
| Blunt | 327,246 (96.2%) | 127,254 (93.5%) | 107,166 (97.6%) | 68,275 (98.4%) | 24,551 (98.9%) | |
| Penetrating | 2786 (0.8%) | 2338 (1.7%) | 317 (0.3%) | 113 (0.2%) | 18 (0.1%) | |
| Other† | 10064 (3.0%) | 6514 (4.8%) | 2286 (2.1%) | 1000 (1.4%) | 264 (1.1%) | |
| Presence of protective devices, n (%) | 99,020 (29.1%) | 47,800 (35.1%) | 30,305 (27.6%) | 16,523 (23.8%) | 4392 (17.7%) | <0.001 |
| Subdural <0.6 cm, n (%) | 68,468 (20.1%) | 26,748 (19.7%) | 21,635 (19.7%) | 14,382 (20.7%) | 5703 (23.0%) | <0.001 |
| Subdural 0.6–1 cm, n (%) | 119,126 (35.0%) | 44,876 (33.0%) | 39,893 (36.3%) | 25,332 (36.5%) | 9025 (36.3%) | <0.001 |
| Subdural >1 cm, n (%) | 38,943 (11.5%) | 11,158 (8.2%) | 13,818 (12.6%) | 9848 (14.2%) | 4119 (16.6%) | <0.001 |
| Bilateral subdural 2–sides 0.6–1 cm, n (%) | 114,310 (33.6%) | 42,654 (31.3%) | 38,308 (34.9%) | 24,497 (35.3%) | 8851 (35.6%) | <0.001 |
| Bilateral subdural with 1-side >1 cm, n (%) | 7156 (2.1%) | 1959 (1.4%) | 2613 (2.4%) | 1824 (2.6%) | 760 (3.1%) | <0.001 |
| Nondisplaced skull fracture, n (%) | 16,885 (5.0%) | 11,322 (8.3%) | 3571 (3.3%) | 1584 (2.3%) | 408 (1.6%) | <0.001 |
| Skull fracture with CSF leak, n (%) | 636 (0.2%) | 445 (0.3%) | 106 (0.1%) | 74 (0.1%) | 11 (<1%) | <0.001 |
| Comminuted skull fracture <2 cm, n (%) | 3720 (1.1%) | 2787 (2.0%) | 622 (0.6%) | 260 (0.4%) | 51 (0.2%) | <0.001 |
| Uncal/tonsillar herniation | 2605 (0.8%) | 943 (0.7%) | 824 (0.8%) | 585 (0.8%) | 253 (1.0%) | <0.001 |
| Abbreviated Injury Scale Score, n (%) | | | | | | <0.001 |
| III | 67,376 (19.8%) | 26,223 (19.3%) | 21,323 (19.4%) | 14,189 (20.4%) | 5641 (22.7%) | |
| IV | 220,923 (65.0%) | 94,019 (69.1%) | 70,310 (64.1%) | 42,474 (61.2%) | 14,120 (56.9%) | |
| V | 51,797 (15.2%) | 15,864 (11.7%) | 18,136 (16.5%) | 12,725 (18.3%) | 5072 (20.4%) | |
| Injury Severity Score, n (%) | | | | | | <0.001 |
| Moderate (9–15) | 64,252 (18.9%) | 24,488 (18.0%) | 20,492 (18.7%) | 13,777 (19.9%) | 5495 (22.1%) | |
| Severe (16–24) | 221,052 (65.0%) | 93,877 (69.0%) | 70,480 (64.2%) | 42,517 (61.3%) | 14,178 (57.1%) | |
| Very severe ≥25 | 54,792 (16.1%) | 17,741 (13.0%) | 18,797 (17.1%) | 13,094 (18.9%) | 5160 (20.8%) | |
| **Hospital characteristic** | | | | | | |
| Hospital Tier, n (%) | | | | | | <0.001 |
| University | 146,208 (43.0%) | 61,021 (44.8%) | 45,749 (41.7%) | 28,968 (41.7%) | 10,470 (42.2%) | |
| Non-teaching | 59,926 (17.6%) | 22,743 (16.7%) | 20,404 (18.6%) | 12,525 (18.1%) | 4254 (17.1%) | |
| Community | 132,584 (39.0%) | 51,904 (38.1%) | 43,199 (39.4%) | 27,552 (39.7%) | 9929 (40.0%) | |
| Others‡ | 1378 (0.4%) | 438 (0.3%) | 417 (0.4%) | 343 (0.5%) | 180 (0.7%) | |
| **Emergency department** | | | | | | |
| Discharge disposition, n (%) | | | | | | <0.001 |
| Home | 6176 (1.8%) | 3202 (2.4%) | 1784 (1.6%) | 923 (1.3%) | 267 (1.1%) | |
| Intensive care unit | 171,699 (50.5%) | 67,817 (49.8%) | 55,032 (50.1%) | 35,711 (51.5%) | 13,139 (52.9%) | |
| Inpatient unit | 148,292 (43.6%) | 60,162 (44.2%) | 48,185 (43.9%) | 29,643 (42.7%) | 10,302 (41.5%) | |
| Other§ | 13,929 (4.1%) | 4925 (3.6%) | 4768 (4.3%) | 3111 (4.5%) | 1125 (4.5%) | |

*continued*

**TABLE 1.**
**(continued.)**

| | Modified Frailty Index-5 | | | | | |
|---|---|---|---|---|---|---|
| | Nonoperative Traumatic Subdural Hemorrhage | | | | | |
| Variables | Total N = 340,096 | Robust N = 136,106 | Normal N = 109,769 | Frail N = 69,388 | Very Frail N = 24,833 | *P* |
| **Outcomes** | | | | | | |
| Hospital length of stay, median (IQR), days | 2.1 (0.4, 4.2) | 1.8 (0.4, 3.8) | 2.2 (0.4, 4.2) | 2.7 (0.5, 4.6) | 3.0 (0.5, 5.0) | <0.001 |
| Intensive care unit length of stay, median (IQR) | 2.0 (2.0, 3.0) | 2.0 (1.0, 3.0) | 2.0 (2.0, 3.0) | 2.0 (2.0, 4.0) | 2.0 (2.0, 4.0) | <0.001 |
| Any hospital complication, n (%) | 32,046 (9.4%) | 13,152 (9.7%) | 9414 (8.6%) | 6664 (9.6%) | 2816 (11.3%) | <0.001 |
| Hospital discharge disposition, n (%) | | | | | | <0.001 |
| Home | 203,564 (59.9%) | 93,289 (68.5%) | 63,502 (57.9%) | 35,897 (51.7%) | 10,876 (43.8%) | |
| High level of care | 96,312 (28.3%) | 25,214 (18.5%) | 34,113 (31.1%) | 25,883 (37.3%) | 11,102 (44.7%) | |
| Other‖ | 40,220 (11.8%) | 17,603 (12.9%) | 12,154 (11.1%) | 7608 (11.0%) | 2855 (11.5%) | |
| Withdrawal of care, n (%) | 6688 (2.0%) | 1366 (1.0%) | 2404 (2.2%) | 1930 (2.8%) | 988 (4.0%) | <0.001 |
| Mortality, n (%) | 24,282 (7.1%) | 7822 (5.7%) | 7772 (7.1%) | 5867 (8.5%) | 2821 (11.4%) | <0.001 |

*Other: American Indian/Alaska Native, Native Hawaiian/Pacific Islander, and Unknown.
†Injury mechanism unspecified.
‡Hospital tier unspecified.
§Emergency department discharge unspecified.
‖Hospital discharge unspecified.
CSF indicates cerebrospinal fluid; IQR, interquartile range.

(5,867/69,388), and very frail 11.4% (2,821/24,833), $P < 0.001$. We observed that 2.0% of the cohort experienced a withdrawal of care. A comparable, gradual increase in rates was also observed across different risk strata, as defined by the mFI-5 (Table 1).

### *Operative tSDH Cohort*

Patients who underwent surgical hematoma evacuation had a median age of 71.0 (IQR: 57.0, 80.0) and demographic characteristics similar to the nonoperative tSDH cohort (Table 2). The most frequent cause of tSDH was blunt trauma 94.4% (39,306/41,658), other prominent injury characteristics included: AIS score V 54.5% (22,718/41,658), and very severe ISS (≥25) 57.9% (24,132/41,658) and a tSDH size of >1 cm 49.8% (20,725/41,658) (Table 2). Forty-six percent (19,174/41,658) were dispositioned to the ICU with a median ICU LOS of 5 days (IQR: 3.0, 9.0). The median time to a craniotomy was 8.8 hours (2.9, 25.5), and a majority of patient had a craniotomy at ≥4 hours 73.4% (30,591/41,658). Patients had a median LOS of 5.0 days (IQR: 2.2, 9.7), and there were sustained increases for frail (5.2 days [IQR: 1.7, 10.1]) and very frail (5.3 days [IQR: 0.5,11.9]) patients, $P < 0.001$. The hospital complication rate was 38.4% (16,011/41,658), and the overall major complication (CD III–IV) rate was 34.5% (14,374/41,658). Frail 35.2% (3,090/8,801) and very frail 40.7% (1,077/2,648) patients experienced a major complication. Patients were more likely discharged to a higher-level of care facility 53.7% (22,363/41,658) (Table 2). These rates increased across mFI-5 strata in the operative cohort (Table 2). There was an overall 14.9% (6,224/41,658) mortality rate, with 16.9% (1,486/8,801) mortality rate for frail patients and a 23.4% (620/2,648) mortality rate for very frail patients, $P < 0.001$. Similarly, care was withdrawn for 3.1% of the cohort. A corresponding progressive rise in rates was also observed across the various risk strata as classified by the mFI-5 (Table 2).

Delineated by TBI severity, patients with severe TBI were more likely to have a higher AIS score (V), and very severe ISS score (≥25) (Table 3). Operative patients in the mild TBI category had a longer time to craniotomy 15.4 hours (IQR: 4.5, 35.1) and were most likely to receive a procedure ≥4 hours 85.9% (24,862/28,931) (Table 3).

### *Risk-Adjusted Analyses*

On multivariable analyses, we observed a stepwise dose-response relationship with our outcomes.

For nonoperatively managed patients (340,096), frail patients had a 19% increased risk of a longer LOS (IRR: 1.19, 95% CI: 1.16, 1.21), $P < 0.001$ and very frail patients experienced a 35% increased risk (IRR: 1.35, 95% CI: 1.32, 1.39), $P < 0.001$ (Table 4). Very frail patients had a 20% increased risk of mortality (HR: 1.20, 95% CI: 1.13, 1.26), $P < 0.001$. Frail patients also experienced a 16% increased risk for discharges to a high level of care facility (OR: 1.16, 95% CI: 1.13, 1.18), $P < 0.001$, and very frail a 54% increased risk (OR: 1.54, 95% CI: 1.50, 1.59), $P < 0.001$ (Table 4).

In the operative cohort (Table 5), frail patients had 46% increased risk for major complications (OR: 1.46, 95% CI: 1.37, 1.56), $P < 0.001$ and very frail a 92% increased risk (OR: 1.92, 95% CI: 1.74, 2.11), $P < 0.001$ (Table 5). Similar increases were observed in this cohort, for LOS; frail patients had a 15% increased risk (IRR: 1.15, 95% CI: 1.09, 1.20), $P < 0.001$, and the very frail experienced a 22% increased risk (IRR: 1.22, 95% CI: 1.13, 1.31), $P < 0.001$. For mortality, frail patients had a 10% increased risk (HR: 1.10, 95% CI: 1.03, 1.17), $P \leq 0.05$, while the very frail experienced a 46% increased risk (HR: 1.46, 95% CI: 1.38, 1.55), $P < 0.001$. Also, for discharges to a high level of care facility, frail patients had a 50% increased risk (OR: 1.50, 95% CI: 1.40, 1.60), $P < 0.001$, and the very frail patients had a >twofold increased risk (OR: 2.34, 95% CI: 2.10, 2.62), $P < 0.001$ (Table 5).

Of note, in both cohorts, a GCS score ≤8 was consistently found to be independently associated with poorer postoperative outcomes. However, the relationship between very severe ISS and outcomes varied (Tables 4 and 5).

**TABLE 2.**

**Demographics, Institutional, Procedural and Clinical Characteristics of Operative Adult Traumatic Subdural Hemorrhage Patients in ACS-TQIP from 2007 to 2020 (N = 41,658)**

| | Modified Frailty Index-5 | | | | | |
|---|---|---|---|---|---|---|
| | Operative Traumatic Subdural Hemorrhage | | | | | |
| Variables | Total N = 41,658 | Robust N = 15,753 | Normal N = 14,456 | Frail N = 8801 | Very frail N = 2648 | *P* |
| **Demographics** | | | | | | |
| Age, median (IQR), years | 71.0 (57.0, 80.0) | 59.0 (44.0, 75.0) | 75.0 (64.0, 82.0) | 75.0 (67.0, 82.0) | 77.0 (69.0, 82.0) | <0.001 |
| Sex, n (%) | | | | | | <0.001 |
| Male | 27,832 (66.8%) | 11,030 (70.0%) | 9330 (64.5%) | 5753 (65.4%) | 1719 (64.9%) | |
| Female | 13,826 (33.2%) | 4723 (30.0%) | 5126 (35.5%) | 3048 (34.6%) | 929 (35.1%) | |
| Race, n (%) | | | | | | <0.001 |
| White | 30,767 (73.9%) | 10,963 (69.6%) | 11,293 (78.1%) | 6511 (74.0%) | 2000 (75.5%) | |
| Black | 4522 (10.9%) | 1728 (11.0%) | 1415 (9.8%) | 1046 (11.9%) | 333 (12.6%) | |
| Asian | 1127 (2.7%) | 403 (2.6%) | 340 (2.4%) | 292 (3.3%) | 92 (3.5%) | |
| Other* | 5242 (12.6%) | 2659 (16.9%) | 1408 (9.7%) | 952 (10.8%) | 223 (8.4%) | |
| Ethnicity, n (%) | 3713 (8.9%) | 1932 (12.3%) | 893 (6.2%) | 714 (8.1%) | 174 (6.6%) | <0.001 |
| Hispanic | | | | | | |
| **Vitals** | | | | | | |
| Glasgow Coma Score ≥13, n (%) | 28,931 (69.5%) | 9740 (61.8%) | 10,663 (73.8%) | 6578 (74.7%) | 1950 (73.6%) | <0.001 |
| Glasgow Coma Score 9–12, n (%) | 4979 (12.0%) | 1995 (12.7%) | 1668 (11.5%) | 979 (11.1%) | 337 (12.7%) | <0.001 |
| Glasgow Coma Score <8, n (%) | 7748 (18.6%) | 4018 (25.5%) | 2125 (14.7%) | 1244 (14.1%) | 361 (13.6%) | <0.001 |
| **Injury Mechanism and Characteristics** | | | | | | |
| Injury Mechanism, n (%) | | | | | | <0.001 |
| Blunt | 39,306 (94.4%) | 14,279 (90.6%) | 13,922 (96.3%) | 8527 (96.9%) | 2578 (97.4%) | |
| Penetrating | 522 (1.3%) | 437 (2.8%) | 57 (0.4%) | 24 (0.3%) | 4 (0.2%) | |
| Other† | 1830 (4.4%) | 1037 (6.6%) | 477 (3.3%) | 250 (2.8%) | 66 (2.5%) | |
| Presence of Protective devices, n (%) | 16,372 (39.3%) | 6845 (43.5%) | 5628 (38.9%) | 3105 (35.3%) | 794 (30.0%) | <0.001 |
| Subdural <0.6 cm, n (%) | 620 (1.5%) | 251 (1.6%) | 202 (1.4%) | 113 (1.3%) | 54 (2.0%) | 0.02 |
| Subdural 0.6–1 cm, n (%) | 6157 (14.8%) | 2384 (15.1%) | 2127 (14.7%) | 1285 (14.6%) | 361 (13.6%) | 0.20 |
| Subdural >1 cm, n (%) | 20,725 (49.8%) | 6634 (42.1%) | 7672 (53.1%) | 4851 (55.1%) | 1568 (59.2%) | <0.001 |
| Bilateral Subdural 2–Sides 0.6–1 cm, n (%) | 6136 (14.7%) | 2316 (14.7%) | 2135 (14.8%) | 1314 (14.9%) | 371 (14.0%) | 0.71 |
| Bilateral Subdural with 1-side >1 cm, n (%) | 3953 (9.5%) | 1220 (7.7%) | 1441 (10.0%) | 991 (11.3%) | 301 (11.4%) | <0.001 |
| Nondisplaced Skull fracture, n (%) | 1243 (3.0%) | 904 (5.7%) | 222 (1.5%) | 101 (1.1%) | 16 (0.6%) | <0.001 |
| Skull fracture with CSF leak, n (%) | 62 (0.2%) | 46 (0.3%) | 10 (0.1%) | 6 (0.1%) | 0 (0.0%) | <0.001 |
| Comminuted Skull Fracture <2 cm, n (%) | 524 (1.3%) | 398 (2.5%) | 96 (0.7%) | 25 (0.3%) | 5 (0.2%) | <0.001 |
| Uncal/Tonsillar Herniation | 1216 (2.9%) | 481 (3.1%) | 401 (2.8%) | 249 (2.8%) | 85 (3.2%) | 0.37 |
| Abbreviated Injury Scale Score, n (%) | | | | | | <0.001 |
| III | 585 (1.4%) | 240 (1.5%) | 189 (1.3%) | 104 (1.2%) | 52 (2.0%) | |
| IV | 18,355 (44.1%) | 8196 (52.0%) | 5862 (40.6%) | 3383 (38.4%) | 914 (34.5%) | |
| V | 22,718 (54.5%) | 7317 (46.4%) | 8405 (58.1%) | 5314 (60.4%) | 1682 (63.5%) | |
| Injury Severity Score, n (%) | | | | | | <0.001 |
| Moderate (9–15) | 485 (1.2%) | 171 (1.1%) | 164 (1.1%) | 98 (1.1%) | 52 (2.0%) | |
| Severe (16–24) | 17,041 (40.9%) | 7401 (47.0%) | 5557 (38.4%) | 3213 (36.5%) | 870 (32.9%) | |
| Very Severe ≥25 | 24,132 (57.9%) | 8181 (51.9%) | 8735 (60.4%) | 5490 (62.4%) | 1726 (65.2%) | |
| **Hospital Characteristic** | | | | | | |
| Hospital Tier, n (%) | | | | | | <0.001 |
| University | 17,689 (42.5%) | 7002 (44.4%) | 5880 (40.7%) | 3693 (42.0%) | 1114 (42.1%) | |
| Non-teaching | 6439 (15.5%) | 2315 (14.7%) | 2359 (16.3%) | 1379 (15.7%) | 386 (14.6%) | |
| Community | 17442 (41.9%) | 6418 (40.7%) | 6182 (42.8%) | 3711 (42.2%) | 1131 (42.7%) | |
| Others‡ | 88 (0.2%) | 18 (0.1%) | 35 (0.2%) | 18 (0.2%) | 17 (0.6%) | |
| **Emergency Department** | | | | | | |
| Discharge Disposition, n (%) | | | | | | <0.001 |
| Home | 112 (0.3%) | 66 (0.4%) | 31 (0.2%) | 13 (0.1%) | 2 (0.1%) | |
| Intensive Care Unit | 19,174 (46.0%) | 6520 (41.4%) | 6917 (47.8%) | 4378 (49.7%) | 1359 (51.3%) | |
| Inpatient Unit | 19,655 (47.2%) | 8222 (52.2%) | 6469 (44.7%) | 3847 (43.7%) | 1117 (42.2%) | |
| Other§ | 2717 (6.5%) | 945 (6.0%) | 1039 (7.2%) | 563 (6.4%) | 170 (6.4%) | |

*continued*

**TABLE 2.**
**(continued.)**

| | Modified Frailty Index-5 | | | | | |
|---|---|---|---|---|---|---|
| | Operative Traumatic Subdural Hemorrhage | | | | | |
| Variables | Total N = 41,658 | Robust N = 15,753 | Normal N = 14,456 | Frail N = 8801 | Very frail N = 2648 | *P* |
| **Procedural Characteristics** | | | | | | |
| Time to Craniotomy, median (IQR) hours | 8.8 (2.9, 25.5) | 5.7 (2.4, 22.0) | 11.0 (3.2, 27.7) | 12.3 (3.4, 32.5) | 13.7 (3.6, 35.3) | <0.001 |
| Time to Craniotomy, n (%) | | | | | | <0.001 |
| Within 1 hour | 1527 (3.7%) | 772 (4.9%) | 439 (3.0%) | 244 (2.8%) | 72 (2.7%) | |
| Within 2 hours | 4649 (11.2%) | 2284 (14.5%) | 1364 (9.4%) | 801 (9.1%) | 200 (7.6%) | |
| Within 3 hours | 4891 (11.7%) | 2185 (13.9%) | 1568 (10.9%) | 871 (9.9%) | 267 (10.1%) | |
| ≥ 4 hours | 30,591 (73.4%) | 10,512 (66.7%) | 11,085 (76.7%) | 6885 (78.2%) | 2109 (79.7%) | |
| **Outcomes** | | | | | | |
| Hospital Length of Stay, median (IQR) | 5.0 (2.2, 9.7) | 4.9 (2.5, 9.7) | 5.0 (2.2, 8.7) | 5.2 (1.7, 10.1) | 5.3 (0.5, 11.9) | <0.001 |
| Intensive Care Unit Length of Stay, median (IQR) | 5.0 (3.0, 9.0) | 5.0 (3.0, 9.0) | 5.0 (3.0, 8.0) | 5.0 (3.0, 9.0) | 6.0 (4.0, 10.0) | <0.001 |
| Any Hospital Complication, n (%) | 16,011 (38.4%) | 6131 (38.9%) | 5193 (35.9%) | 3472 (39.5%) | 1215 (45.9%) | <0.001 |
| Complications, n (%)‖ | | | | | | |
| I | 12 (<0.1%) | 4 (<1%) | 4 (<1%) | 4 (<1%) | 0 (0.0%) | 0.64 |
| II | 1625 (3.9%) | 566 (3.6%) | 543 (3.8%) | 378 (4.3%) | 138 (5.2%) | <0.001 |
| III | 1748 (4.2%) | 636 (4.0%) | 589 (4.1%) | 401 (4.6%) | 122 (4.6%) | 0.14 |
| IV | 12,626 (30.3%) | 4925 (31.3%) | 4057 (28.1%) | 2689 (30.6%) | 955 (36.1%) | <0.001 |
| Hospital Discharge Disposition, n (%) | | | | | | <0.001 |
| Home | 14,052 (33.7%) | 6637 (42.1%) | 4667 (32.3%) | 2281 (25.9%) | 467 (17.6%) | |
| High Level of Care | 22,363 (53.7%) | 7162 (45.5%) | 8145 (56.3%) | 5348 (60.8%) | 1708 (64.5%) | |
| Other¶ | 5243 (12.6%) | 1954 (12.4%) | 1644 (11.4%) | 1172 (13.3%) | 473 (17.9%) | |
| Withdrawal of Care, n (%) | 1270 (3.1%) | 296 (1.9%) | 471 (3.3%) | 346 (4.0%) | 157 (6.0%) | <0.001 |
| Mortality, n (%) | 6224 (14.9%) | 2083 (13.2%) | 2035 (14.1%) | 1486 (16.9%) | 620 (23.4%) | <0.001 |

*Other: American Indian/Alaska Native, Native Hawaiian/Pacific Islander, and Unknown.
†Injury mechanism unspecified.
‡Hospital tier unspecified.
§Emergency department discharge unspecified.
‖Complications, consists of all postoperative complications categorized by Clavein-Dindo classification; grades range from 0 (no complications) to IV (life-threatening complications).
¶Hospital discharge unspecified.
CSF indicates cerebrospinal fluid; IQR, interquartile range.

### *Survival Analyses*

On K-M plots, we saw a significant decrease in the probability of survival within the first 100 days after tSDH. This was observed in the frail and very frail group and cox proportional models portrayed an increased mortality risk in these patient groups (Figure 2). Stratified by nonoperative and operative tSDH patients, a similar trend for both K-M and cox proportion models were observed (Figure 3A,B). Figures 4 and 5 graphically demonstrate the marked stepwise decline in observed and expected survival probabilities across mFI-5 frailty risk strata. This stepwise decline is particularly seen in frail and very frail patients underscoring the severe impact of frailty on patient outcomes.

## DISCUSSION

In this retrospective cohort study of 381,754 patients with tSDH, frailty was associated with increased risk for major complications, increased LOS, mortality, and discharge to a higher-level of care facility. Furthermore, increased frailty, as stratified by mFI-5, displayed a significant stepwise dose-dependent relationship to these adverse outcomes. Observed survival rates were substantially lower than expected in both the nonoperative and operative cohort. This is a call to action for more research to determine the precise impact of frailty on patient outcomes with TBI, and ultimately inform clinical decision-making.

In our study, frail tSDH patients had an extended time to life-saving craniotomy, regardless of tSDH size. In prior investigations, the effect of time to craniotomy has been inconsistent.[35–39] Wilberger et al report that the extent of the underlying brain injury is more important than the presence or absence of a subdural hemorrhage itself in predicting outcome, that is, perioperative ICP control is more critical to outcome than the timing of hematoma evacuation.[36] Rawanduzy and colleagues examined frailty's impact on tSDH in TBI patients to determine the predictive efficiency of initial GCS in relation to three frailty indicators (mFI-5, temporalis muscle thickness, and age-adjusted Charlson Comorbidity Index). Frailty was a predictor of poor outcomes, even though initial GCS had better predictive ability, as expected.[4] Another tSDH study found that increasing frailty was associated with longer hospital stays and nonroutine discharges but not mortality.[40] The authors noted that the cohort's higher than expected GCS scores (nonoperative GCS ≥13: 85.2%, and operative 69.5%) were a possible explanation for the low mortality rates observed. Consistent with the typically lower-impact injuries in older patients, often presenting with mixed density subdural hematomas, whereas younger patients experience more high-velocity injuries.[40]

**TABLE 3.**

**Clinical Characteristics of Adult Traumatic Subdural Hemorrhage Patients in ACS-TQIP from 2007 to 2020 Delineated by Mild, Moderate and Severe Traumatic Brain Injury Classification**

| (A)Traumatic Brain Injury Classification in the Nonoperative Cohort | | | | | |
|---|---|---|---|---|---|
| Variables | Total N = 340,096 | Mild (GCS ≥13) N = 289,772 | Moderate (GCS 9–12) N = 26,464 | Severe (GCS ≤8) N = 23,860 | *P* |
| **Injury mechanism and characteristics** | | | | | |
| Abbreviated Injury Scale Score, n (%) | | | | | <0.001 |
| III | 67,376 (19.8%) | 61,133 (21.1%) | 4074 (15.4%) | 2169 (9.1%) | |
| IV | 220,923 (65.0%) | 192,347 (66.4%) | 17,281 (65.3%) | 11,295 (47.3%) | |
| V | 51,797 (15.2%) | 36,292 (12.5%) | 5109 (19.3%) | 10,396 (43.6%) | |
| Injury Severity Score, n (%) | | | | | <0.001 |
| Moderate (9–15) | 64,252 (18.9%) | 58,483 (20.2%) | 3865 (14.6%) | 1904 (8.0%) | |
| Severe (16–24) | 221,052 (65.0%) | 194,451 (67.1%) | 17,159 (64.8%) | 9442 (39.6%) | |
| Very Severe ≥25 | 54,792 (16.1%) | 36,838 (12.7%) | 5440 (20.6%) | 12,514 (52.4%) | |
| **(B)Traumatic Brain Injury Classification in the Operative Cohort** | | | | | |
| | Total N = 41,658 | Mild (GCS ≥13) N = 28,931 | Moderate (GCS 9–12) N = 4,979 | Severe (Severe ≤8) N = 7,748 | *P* |
| **Injury mechanism and characteristics** | | | | | |
| Abbreviated Injury Scale Score, n (%) | | | | | <0.001 |
| III | 585 (1.4%) | 448 (1.5%) | 62 (1.2%) | 75 (1.0%) | |
| IV | 18,355 (44.1%) | 12,962 (44.8%) | 2321 (46.6%) | 3072 (39.6%) | |
| V | 22,718 (54.5%) | 15,521 (53.6%) | 2596 (52.1%) | 4601 (59.4%) | |
| Injury Severity Score, n (%) | | | | | <0.001 |
| Moderate (9–15) | 485 (1.2%) | 379 (1.3%) | 53 (1.1%) | 53 (0.7%) | |
| Severe (16–24) | 17,041 (40.9%) | 12,700 (43.9%) | 2168 (43.5%) | 2173 (28.0%) | |
| Very severe ≥25 | 24,132 (57.9%) | 15,852 (54.8%) | 2758 (55.4%) | 5522 (71.3%) | |
| **Procedural characteristics** | | | | | |
| Time to craniotomy, median (IQR) hours | 8.8 (2.9, 25.5) | 15.4 (4.5, 35.1) | 5.7 (2.5, 22.5) | 2.1 (1.4, 3.5) | <0.001 |
| Time to craniotomy, n (%) | | | | | |
| Within 1 hour | 1527 (3.7%) | 426 (1.5%) | 192 (3.9%) | 909 (11.7%) | <0.001 |
| Within 2 hours | 4649 (11.2%) | 1301 (4.5%) | 631 (12.7%) | 2717 (35.1%) | |
| Within 3 hours | 4891 (11.7%) | 2342 (8.1%) | 754 (15.1%) | 1795 (23.2%) | |
| ≥4 hours | 30,591 (73.4%) | 24,862 (85.9%) | 3402 (68.3%) | 2327 (30.0%) | |

GCS indicates Glasgow Coma Score.

**TABLE 4.**

**Risk-Adjusted Associations Between Frailty Risk Strata and Outcomes in Nonoperative Adult Traumatic Subdural Hemorrhage Patients in ACS-TQIP from 2007 to 2020 (n = 340,096)**

| Variables | LOS IRR (95% CI) | Mortality HR (95% CI) | High Level of Care Discharge OR (95% CI) |
|---|---|---|---|
| **Robust (mFI-5 = 0)** | **[REF]** | **[REF]** | **[REF]** |
| Normal (mFI-5 = 1) | 1.10 (1.07, 1.12)* | 0.89 (0.87, 0.92)* | 0.96 (0.94, 0.98)* |
| Frail (mFI-5 = 2) | 1.19 (1.16, 1.21)* | 0.97 (0.92, 1.02)† | 1.16 (1.13, 1.18)* |
| Very frail (mFI-5 ≥3) | 1.35 (1.32, 1.39)* | 1.20 (1.13, 1.26)* | 1.54 (1.50, 1.59)* |
| **Age** | 1.00 (1.00, 1.00)* | 1.03 (1.03, 1.04)* | 1.04 (1.04, 1.04)* |
| **Male** | **[REF]** | **[REF]** | **[REF]** |
| Female | 0.90 (0.89, 0.91)* | 0.88 (0.86, 0.91)* | 1.00 (0.98, 1.01)† |
| **White** | **[REF]** | **[REF]** | **[REF]** |
| Nonwhite | 1.04 (1.03, 1.04)* | 0.94 (0.92, 0.95)* | 0.93 (0.92, 0.94)* |
| **GCS (>13)** | **[REF]** | **[REF]** | **[REF]** |
| GCS (9–12) | 1.48 (1.45, 1.52)* | 2.59 (2.47, 2.72)* | 2.02 (1.96, 2.08)* |
| GCS (≤8) | 1.51 (1.46, 1.56)* | 9.10 (8.41, 9.85)* | 6.70 (6.48, 6.94)* |
| **ISS (Moderate)** | **[REF]** | **[REF]** | **[REF]** |
| ISS (severe) | 1.59 (1.49, 1.70)* | 0.88 (0.69, 1.13) - | 1.94 (1.79, 2.10)* |
| ISS (very severe) | 1.44 (1.29, 1.62)* | 5.74 (4.40, 7.48)* | 18.86 (16.19, 22.00)* |
| **AISS (III)** | **[REF]** | **[REF]** | **[REF]** |
| AISS (IV) | 0.75 (0.71, 0.80)* | 1.53 (1.22, 1.91)* | 0.72 (0.67, 0.78)* |
| AISS (V) | 0.98 (0.87, 1.09)† | 0.79 (0.63, 1.00)† | 0.16 (0.14, 0.19)* |

*$P < 0.001$,

†$P > 0.05$.

AISS indicates abbreviated injury scale score; CI, confidence interval; GCS, Glasgow Coma Score; HR, hazard ratio; IRR, incidence rate ratio; ISS, injury severity score; LOS, length of stay; mFI-5, modified frailty index-5; OR, odds ratio.

**TABLE 5.**

**Risk-Adjusted Associations Between Frailty Risk Strata and Outcomes in Operative Adult Traumatic Subdural Hemorrhage Patients in ACS-TQIP From 2007 to 2020 (n=41,658)**

| Variables | Major Complications OR (95% CI) | LOS IRR (95% CI) | Mortality HR (95% CI) | High Level of Care Discharge OR (95% CI) |
|---|---|---|---|---|
| **Robust (mFI-5 = 0)** | [REF] | [REF] | [REF] | [REF] |
| Normal (mFI-5 = 1) | 1.21 (1.15, 1.28)* | 1.07 (1.03, 1.12)* | 0.94 (0.87, 1.01)‡ | 1.13 (1.07, 1.19)* |
| Frail (mFI-5 = 2) | 1.46 (1.37, 1.56)* | 1.15 (1.09, 1.20)* | 1.10 (1.03, 1.17)† | 1.50 (1.40, 1.60)* |
| Very frail (mFI-5 ≥3) | 1.92 (1.74, 2.11)* | 1.22 (1.13, 1.31)* | 1.46 (1.38, 1.55)* | 2.34 (2.10, 2.62)* |
| **Age** | 0.99 (0.99, 1.00)* | 0.99 (0.99, 1.00)* | 1.03 (1.03, 1.03)* | 1.04 (1.04, 1.04)* |
| **Male** | [REF] | [REF] | [REF] | [REF] |
| Female | 1.04 (0.99, 1.09)‡ | 0.96 (0.93, 1.00)† | 1.00 (0.95, 1.05)‡ | 1.35 (1.29, 1.42)* |
| **White** | [REF] | [REF] | [REF] | [REF] |
| Nonwhite | 0.97 (0.95, 0.99)† | 1.02 (1.01, 1.04)† | 0.94 (0.92, 0.97)* | 0.92 (0.90, 0.94)* |
| **GCS (>13)** | [REF] | [REF] | [REF] | [REF] |
| GCS (9–12) | 2.48 (2.33, 2.64)* | 1.27 (1.21, 1.33)* | 1.74 (1.60, 1.90)* | 1.99 (1.85, 2.14)* |
| GCS (≤8) | 9.34 (8.79, 9.92)* | 1.31 (1.25, 1.37)* | 4.40 (4.04, 4.79)* | 6.97 (6.42, 7.56)* |
| **ISS (Moderate)** | [REF] | [REF] | [REF] | [REF] |
| ISS (severe) | 1.52 (0.93, 2.29)‡ | 0.74 (0.49, 1.13)‡ | 0.66 (0.42, 1.03)‡ | 1.58 (0.96, 2.60)‡ |
| ISS (very severe) | 3.02 (1.81, 5.04)* | 0.75 (0.49, 1.15)‡ | 2.77 (1.74, 4.42)* | 7.05 (4.14, 12.00)* |
| **AISS (III)** | [REF] | [REF] | [REF] | [REF] |
| AISS (IV) | 0.57 (0.36, 0.90)† | 1.13 (0.80, 1.61)‡ | 1.48 (0.87, 2.51)‡ | 0.74 (0.47, 1.17)‡ |
| AISS (V) | 0.37 (0.23, 0.59)* | 1.07 (0.75, 1.55)‡ | 0.60 (0.34, 1.06)‡ | 0.18 (0.11, 0.29)* |

Major complications, consists of postoperative complications categorized as III and IV by Clavein-Dindo classification.

*$P < 0.001$,

†$P \leq 0.05$, and

‡$P > 0.05$.

AISS indicates abbreviated injury scale score.; CI, confidence interval; GCS, Glasgow Coma Score; HR hazard ratio; IRR, incidence rate ratio; ISS, injury severity score; LOS, length of stay; mFI-5, modified frailty index-5; OR, odds ratio.

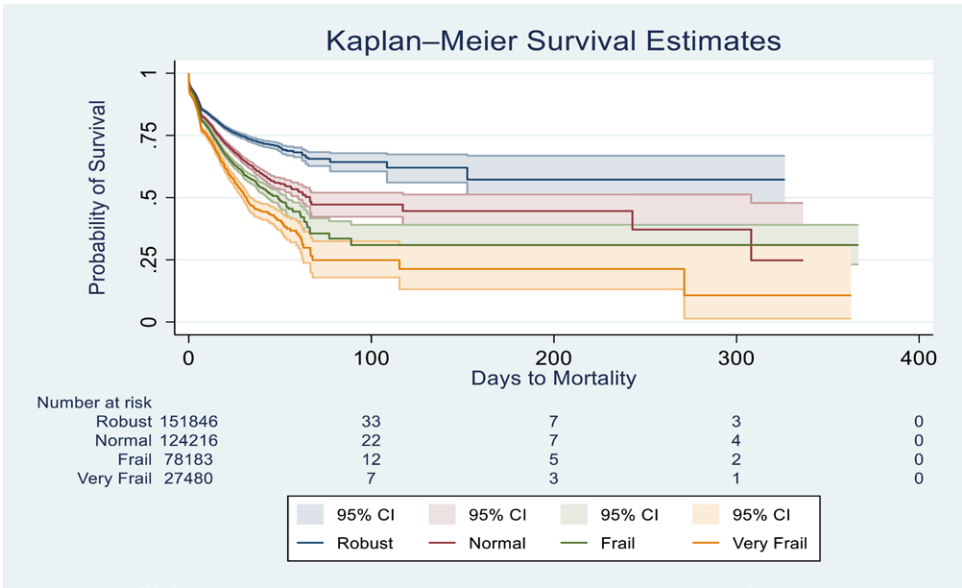


**FIGURE 2.** Survival outcomes of adult patients with acute traumatic subdural hemorrhage in ACS-TQIP (2007–2020). Hazard ratios: robust (mFI-5 = 0) reference, normal (mFI-5 = 1) HR: 1.15 (95% CI 1.07–1.23)*, frail (mFI-5 = 2) HR: 1.31 (95% CI 1.21–1.41)*, very frail (mFI-5 ≥ 3) HR: 1.65 (95% CI 1.54–1.77)*. **P* value <0.001; CI, confidence interval; mFI-5, modified frailty index-5.

Across both cohorts, we observed a significant increase in the rates of care withdrawal with increasing frailty. This aligns with prior studies that underscore the prevalence of high withdrawal rates among this demographic, signifying a pressing healthcare concern.[41,42] The trend accentuates the urgency for refining preoperative decision-making processes and enhancing postoperative care. The elevated withdrawal rates could potentially signal insufficient patient counseling or overly optimistic expectations, indicating a pressing need for more thorough patient education and support systems.[41,42] As ongoing quality improvement efforts in trauma systems reduces morbidity and mortality rates,[43,44] it becomes clear that modifying factors like frailty should be given continued priority. Highlighting the leap forward approach for comprehensive risk assessment and coordinated care. Integrating these elements into our trauma systems can create a more nuanced and effective approach to patient care, ultimately contributing to the overall well-being and quality of life for these high-risk patients, and make more efficient use of healthcare resources.[27,28]

While our study has certain limitations, they warrant careful consideration. Our findings are derived from the ACS-TQIP, an

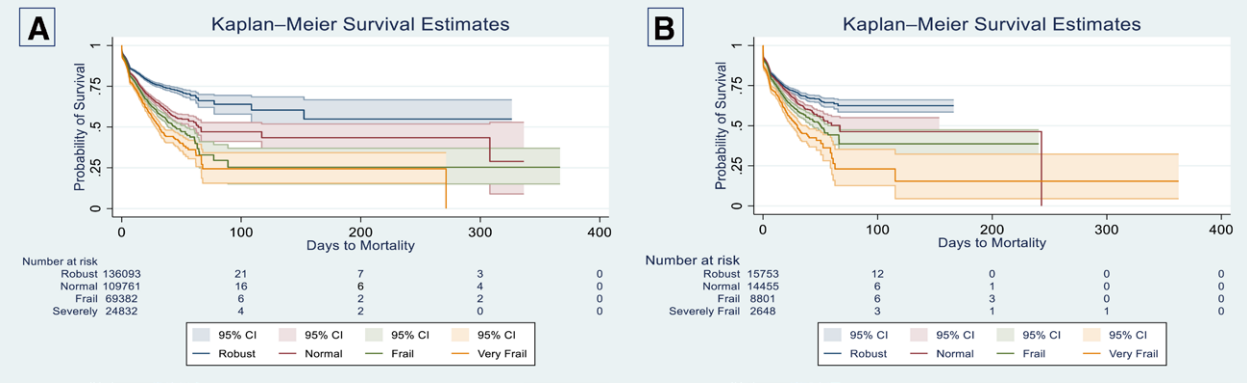


**FIGURE 3.** Survival outcomes of adult patients with acute traumatic subdural hemorrhage in ACS-TQIP (2007–2020) presented by (A) nonoperative and (B) operative management. (A) hazard ratios: robust (mFI-5 = 0) reference, normal (mFI-5 = 1) HR: 1.16 (95% CI 1.08–1.25)*, frail (mFI-5 = 2) HR: 1.31 (95% CI 1.19–1.45)*, very frail (mFI-5 ≥ 3) HR: 1.64 (95% CI 1.52–1.78)*. **P* value <0.001; CI, confidence interval; mFI-5, modified frailty index-5. (B) hazard ratios: robust (mFI-5 = 0) reference, normal (mFI-5 = 1) HR: 1.06 (95% CI 0.99–1.14)-, frail (mFI-5 = 2) HR: 1.25 (95% CI 1.29–1.31)*, very frail (mFI-5 ≥ 3) HR: 1.70 (95% CI 1.58–1.82)*. **P* value <0.001, *P* value ≥0.05; CI, confidence interval; mFI-5, modified frailty index-5.

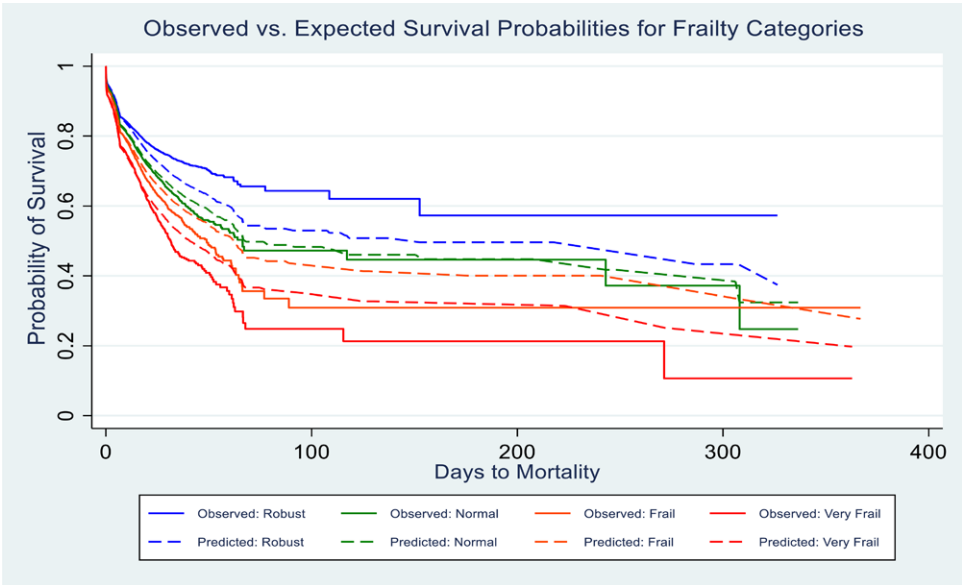


**FIGURE 4.** Overall observed versus expected survival outcomes of adult patients with acute traumatic subdural hemorrhage in ACS-TQIP (2007–2020).

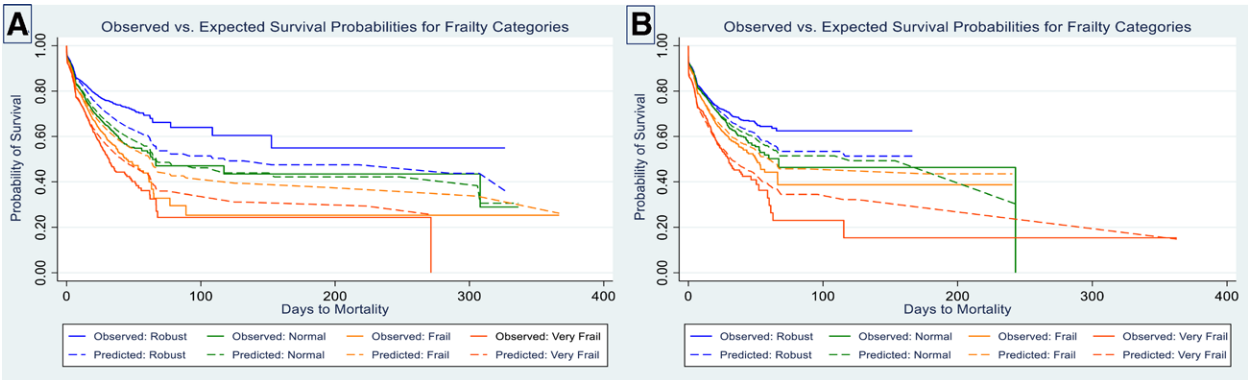


**FIGURE 5.** Observed versus expected survival outcomes of adult patients with acute traumatic subdural hemorrhage in ACS-TQIP (2007–2020) presented by (A) nonoperative and (B) operative management.

incident-based database, and this specificity may affect the generalizability of our results. The study's scope is restricted to patients treated at American College of Surgeons-certified trauma centers within the United States, which means our findings may not translate well to different settings or regions. Moreover, our analysis could be potentially influenced by the quality and organization of the data we utilized, as well as the specific variables available within the database. Coding bias and observer bias may have also had an impact. Consequently, the possibility of misclassification must be recognized. Additionally, our assessment of patient frailty was performed using the modified Frailty Index-5 (mFI-5), which only measures frailty in two domains. This approach could be seen as a limitation, particularly considering the significant changes in data collection that took place over our 14-year

study period. Despite these changes our results demonstrate that the mFI-5 can be an effective tool for predicting outcomes across various ACS-TQIP cohorts, and it can be quickly implemented in acute settings.[25] However, it's important to underscore that our research employs robust statistical methods and algorithms to compensate for these limitations. Our study stands out as one of the few that have used the mFI-5 to assess frailty risk for tSDH patients, offering valuable insights for postoperative survival and mortality rates. This makes our work not only unique but also significant in the continuing pursuit of improving patient care.

## CONCLUSIONS

In a nationwide retrospective cohort study encompassing 381,754 tSDH patients, we found a distinct relationship between increasing frailty and a multitude of adverse outcomes. Prompt surgical intervention is crucial for tSDH patients, yet our research suggests that a rapid point-of-care frailty assessment could provide physicians with a valuable tool for resource allocation. This precise approach could potentially enhance patient outcomes. Additionally, our results underline the potential advantages of further investigation in future prospective studies.

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