

# **Surgical Stress and Physiological Reserve: A Novel Framework Predicts Complications and Optimizes Care Pathways in High-Energy Femur Fracture Surgery**

Sumin Jeong, Kole Preston Joachim, Adrian Lin, Brandon Stephen Gettleman, Christopher D Hamad, Amanda Perrotta, Ezekiel Dingle, Alexandra Stavrakis, Alexander Christ

## **INTRODUCTION:**

Postoperative outcomes following high energy femur fracture surgery vary widely, even among similar patients. Existing models often fail to integrate two key factors: surgical stress (procedural burden) and physiologic reserve (the patient's inherent capacity to withstand stress). We developed a novel, data-driven framework to quantify both surgical stress and physiologic reserve using routinely available registry data and evaluated their combined effect on short-term outcomes after femur fracture fixation.

## **METHODS:**

We analyzed 6,118 femur fracture cases from NSQIP (2019-2023), with 3,774 meeting complete data criteria. Using principal component analysis, we derived two indices: a Hemodynamic Stress Index (HSI, incorporating operative time, RVUs, transfusions, bleeding, BMI, and case urgency) and a Physiologic Reserve Score (PRS, based on age, albumin, creatinine, dialysis, functional status, and comorbidities). Patients were stratified into four quadrants: High Stress/Low Reserve (HS/LR, n=1,021), High Stress/High Reserve (HS/HR, n=866), Low Stress/Low Reserve (LS/LR, n=866), and Low Stress/High Reserve (LS/HR, n=1,021). Multivariable regression assessed complications (HS/HR as reference).

## **RESULTS:**

Among the 3,774 patients included in the final analysis, demographic differences were notable: HS/LR patients were older ( $76.7 \pm 11.1$  years) than HS/HR patients ( $62.1 \pm 18.3$  years), with higher BMI ( $32.5 \pm 8.7$  vs.  $31.9 \pm 8.2$ ). LS/LR patients had the highest mean age ( $79.8 \pm 9.8$  years). Patients in the HS/LR quadrant experienced the worst short-term outcomes. Mean length of stay was significantly longer for HS/LR patients compared to LS/HR patients (6.45 vs. 4.91 days). Readmission rates were higher in the HS/LR group compared to LS/HR (9.4% vs. 3.9%), as was the rate of return to the operating room (3.5% vs. 1.5%). After multivariable regression analysis, the HS/LR group demonstrated significantly higher odds of pneumonia (OR=3.31, 95% CI: 1.64-6.68,  $p < 0.001$ ), myocardial infarction (OR=5.57, 95% CI: 1.25-24.76,  $p = 0.024$ ), sepsis (OR=3.16, 95% CI: 1.27-7.82,  $p = 0.013$ ), progressive renal insufficiency (OR=2.73, 95% CI: 1.50-4.96,  $p = 0.001$ ), acute renal failure (OR=5.14, 95% CI: 1.15-23.02,  $p = 0.032$ ), urinary tract infections (OR=2.17, 95% CI: 1.35-3.49,  $p = 0.001$ ), and postoperative bleeding (OR=2.42, 95% CI: 1.99-2.94,  $p < 0.001$ ). The LS/LR group showed significantly increased risk compared to HS/HR for myocardial infarction (OR=11.79, 95% CI: 2.77-50.15,  $p < 0.001$ ), pneumonia (OR=5.36, 95% CI: 2.70-10.62,  $p < 0.001$ ), and acute renal failure (OR=5.05, 95% CI: 1.10-23.10,  $p = 0.037$ ). The LS/HR group showed significantly reduced odds of complications, particularly for deep vein thrombosis (OR=0.42, 95% CI: 0.20-0.87,  $p = 0.019$ ), postoperative bleeding (OR=0.60, 95% CI: 0.48-0.75,  $p < 0.001$ ), and progressive renal insufficiency (OR=0.33, 95% CI: 0.13-0.85,  $p = 0.021$ ).

## **DISCUSSION AND CONCLUSION:**

This framework provides a scalable and interpretable method for risk stratification in patients with femur fractures, utilizing existing registry variables. The quadrant model captures synergistic risk not apparent when considering surgical or physiologic factors in isolation. Clinically, it provides an intuitive tool for perioperative planning, resource allocation, and patient counseling in the management of high-energy femur fractures. Mean complication rates demonstrate a clear hierarchy of risk, suggesting targeted intervention opportunities. Future work may extend this model toward individualized care pathways and automated risk prediction tools for traumatic femur fractures.