

Development of an Enabling Technology Value Index (ETVI) to Quantify the Value of Emerging Technologies in Orthopedic Surgery

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INTRODUCTION: The rapid integration of advanced technologies—including 3D printing, extended reality, finite-element modeling, robotic-assisted surgery, and artificial intelligence—has transformed orthopedic care, enabling improved intraoperative efficacy and safety and more individualized patient care throughout the entire episode of care. However, as healthcare costs escalate, the evaluation and decision framework to assess potential acquisition and utilization needs further development. Specifically, a structured and objective framework is urgently needed to evaluate the value of these enabling technologies. Without such a tool, we risk both overadopting low-impact, high-cost “tools” and underutilizing more transformative innovations. In this study, we propose and present the structure of the Enabling Technology Value Index (ETVI), a novel composite metric designed to guide adoption decisions by aligning stakeholder-centric value with cost.

METHODS: We conducted a comprehensive review of published value assessment frameworks across surgical disciplines, focusing on composite indices that incorporated patient outcomes, provider usability, and cost. Based on this analysis, we identified three key stakeholders in surgical innovation: the patient, the surgeon, and the health system (leadership/administrators). For each stakeholder, we selected a validated and widely accepted proxy variable: patient-reported outcomes (PROs) for patients, the NASA Task Load Index (NASA-TLX) for surgeon workload and ergonomics, and time-driven activity-based costing (TDABC) to capture systemic cost and efficiency. We developed a composite numerator by normalizing each variable to a 0–1 scale and applying dynamic weights based on the presence or absence of available data. Weighting was conducted using a proportional reallocation algorithm to ensure total contribution sums remained constant. The denominator, TDABC, was selected to reflect both direct and indirect resource consumption during surgical care. This structure enables broad generalizability across technologies and procedural settings.

RESULTS:

The resulting Enabling Technology Value Index (ETVI) is a stakeholder-driven composite score that incorporates patient-reported outcomes (PRO), surgeon ergonomics (NASA-TLX), and objective quality metrics (readmission rate) in the numerator, divided by time-driven activity-based costing (TDABC) in the denominator. Each variable maps to a distinct stakeholder: PRO (patient), NASA-TLX (surgeon), and TDABC (health system), and is normalized to a 0–1 scale with dynamic weighting applied if data from any single domain is unavailable. The full model architecture and equation are detailed in Figure 1. Readmission rate is included within the composite score as an objective quality marker augmenting the subjective elements of the numerator. To illustrate the model's function, we applied the ETVI to a spine surgery case example. A hypothetical enabling technology reduced intraoperative time by 15%, improved the Oswestry Disability Index (ODI) by 10 points, and lowered surgeon workload on the NASA-TLX scale. There was no change in 30-day readmission. Cost, calculated using TDABC, was \$9,800. When these metrics were incorporated into the ETVI framework, the enabling technology yielded a higher score relative to a matched control case, reflecting an increase in measured value.

DISCUSSION AND CONCLUSION: The Enabling Technology Value Index (ETVI) represents a novel and methodologically rigorous framework for quantifying the value of emerging surgical technologies in orthopedics. By integrating validated measures of clinical outcomes, surgeon usability, and health system cost into a unified metric, the ETVI offers a comprehensive, stakeholder-aligned approach to evidence-based decisions regarding technology adoption and resource allocation. We are currently working to validate this index across procedural subspecialties, applying it in real-world procurement and technology evaluation settings.