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EDITORIAL

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Lean management in total knee arthroplasty: A model for efficiency and value-based care

Abstract

With rising procedure volumes, cost pressures, and shorter hospital stays, the application of Lean management principles offer substantial promise for the pathway of total knee arthroplasty (TKA). This editorial outlines how Lean and Lean Six Sigma methodologies can be applied to TKA—covering pre-operative pathway standardisation, intra-operative workflow optimisation, implant and instrument logistics, and post-operative care. Evidence shows that process redesign can reduce length of stay, time in the operating room, cancellations, and wasted resources. Key success factors, barriers, future directions and limitations are highlighted, with particular relevance for high-volume arthroplasty centres and revision scenarios. The concept is positioned as a model for clinical innovation in arthroplasty services, aligning with the ambitions of value-based care.

KEYWORDS

efficiency, lean management, total knee arthroplasty, value-based care

INTRODUCTION

In today's orthopaedic practice, particularly in high-volume arthroplasty centres, the current challenge posed by the financial pressures facing most healthcare systems is twofold: maintaining excellent clinical outcomes while delivering care more efficiently. The pathway for primary—and increasingly revision—total knee arthroplasty (TKA) places significant demands on peri-operative logistics, instrumentation, team coordination and post-operative resources. In parallel, health-economics and reimbursement models increasingly emphasise value-based care—a delivery model in which providers are paid based on patient health outcomes rather than the volume of services rendered, incentivising quality over quantity [10, 11, 13, 38].

Lean management—originally derived from industrial manufacturing—is now recognised in healthcare as a framework to systematically improve process flow, eliminate waste and standardise work [5, 6, 13]. Not only is it a cost-cutting exercise but a method to maximise value for patients. To fully understand its potential, one must understand its synergetic partner, Lean Six Sigma. While Lean focuses on speed and the removal of waste (non-value-added steps), Lean Six Sigma focuses on precision and the removal of variability [27, 34]. Together, they form a powerful tool for surgical quality control.

Frameworks utilising these principles have demonstrated measurable benefits in surgery [23, 33]. Recent literature reports the enhancement of surgical pathways and rehabilitation through Lean Six Sigma methodologies, describing Lean pathways in orthopaedics as 'multiple wins' for sustainability by reducing waste, time and cost [23, 33]. One redesign of a joint replacement programme in a Veterans Affairs hospital achieved a 36% reduction in length of stay, attributed to the systematic removal of process inefficiencies and improved discharge coordination [13].

From a clinical and organisational perspective, TKA represents an ideal model for Lean application [1, 36]. Its reproducible and outcome-driven nature allows detailed pathway mapping and targeted process optimisation. This editorial reviews the conceptual framework, clinical relevance, and practical application of Lean principles in TKA, aiming to highlight their broader implications for efficiency and quality in arthroplasty.

LEAN PRINCIPLES AND THEIR RELEVANCE TO TKA

Lean methodology focuses on five core principles: identifying value, mapping the value stream, creating flow, establishing pull and pursuing perfection [18, 37]. In TKA, these translate into:

Abbreviations: ACL, anterior cruciate ligament; CPM, continuous passive motion; DOSA, day-of-surgery admission; PROMS, patient reported outcome measures; TKA, total knee arthroplasty.

- **Value:** Delivering optimal functional outcome, low complication rate and high patient satisfaction.
- **Value-stream mapping:** Analysing every process step—from referral and preoperative assessment to surgery, rehabilitation, and discharge—identifying delays, duplication and variability.
- **Flow:** Ensuring seamless progression through each stage without unnecessary waiting, bottlenecks or redundancy.
- **Pull:** aligning resources such that demand drives supply-ready instrument sets, implant availability and coordinated staff preparation.
- **Perfection:** ongoing monitoring, data-driven refinement (using real-time metrics to adjust protocols) and iterative improvement.

Current research underscores that Lean implementation in healthcare demands leadership, high-quality training, cross-functional teams, and an embedded improvement culture [20, 22]. In orthopaedics, common 'waste points' include late cancellations, prolonged setup time, redundant preoperative testing, inefficient instrument management, delayed mobilisation and prolonged discharge processes—all of which are amenable to resign [15, 30].

WHY LEAN MATTERS: LESSONS FROM HIGH-VOLUME ARTHROPLASTY

The relevance of Lean is most established in high-volume settings where process redesign has yielded measurable benefits. The growing body of evidence supports Lean interventions as both effective and sustainable. Reported benefits include

- Reduced length of stay (by up to 36%) [13]
- Lower cancellation rates [15]
- Improved OR efficiency [32]
- Reduced material and sterilisation costs [29]

In this context standardising preoperative assessment and patient education reduces cancellations and improves scheduling reliability. Implementing day-of-surgery admission (DOSA) and fast-track pathways has been associated with shorter hospital stays and improved throughput [8, 12, 14]. Studies regarding fast-track concepts have demonstrated an improved resource utilisation and bed turnover by using Lean Six Sigma [28]. It is important to distinguish Fast-track from Lean. Fast-track is the clinical protocol (e.g., multimodal analgesia, early mobilisation), whereas Lean is the management system used to identify the barriers to implementing that protocol efficiently.

At high-volume centres, structured preoperative planning—including imaging, laboratory work, anaesthesia clearance and physiotherapy scheduling—creates predictable flow. Value-stream mapping helps eliminate duplicate assessments and waiting times. The result is a smoother admission process and a reduced overall time from referral to discharge [12, 15, 30].

The operating room, the most resource-intensive phase, shows measurable productivity gains through process analysis and communication optimisation. Research into instrument tray optimisation reduced sterilisation workload and unnecessary material use, yielding both economic and ecological benefits [36]. Lean strategies also include benchmarking of operative steps—from anaesthetic induction to patient positioning, incision, component implantation, and closure. Standardised time benchmarks in hip and knee arthroplasty have been shown to significantly reduced variance and improved throughput [16].

Postoperative Lean optimisation focuses on early mobilisation, structured physiotherapy, and coordinated discharge planning. While concepts like early mobilisation are standard in modern arthroplasty, Lean methodology ensures their steps occur reliably for every patient by removing system failures (e.g., lack of available physiotherapists). By eliminating unnecessary postoperative lab testing, routine continuous passive motions (CPM) and prolonged inpatient observation, resource use was reduced without compromising outcomes. These modifications—carefully monitored through PROMs, radiographic evaluation, and survivorship data—showed equivalent or superior clinical results [3, 13]. It should be emphasised, however, that efficiency must never compromise patient safety or quality—a principle to which we remain particularly committed.

Multiple studies have concluded that Lean represents not only a cost-saving measure but a sustainable, patient-centred philosophy that aligns with long-term value-based care [23, 31].

RELEVANCE BEYOND PRIMARY TKA: THE REVISION SCENARIO

While Lean principles are ideal for standardising primary TKA, these concepts are especially relevant complex scenarios. In revision TKA variability is inherently higher and coordination with implant vendors and intraoperative imaging adds complexity. This variability in revision limits standardisation, but Lean and Lean Six Sigma offers structure within variability through predefined contingency pathways. A Lean mindset supports risk-stratified scheduling and anticipatory logistics, reducing important OR time [2, 9]. The application of process discipline is even more essential in revision TKA, where implant selection and variable surgical demands require precise coordination [21, 35].

The application of these principles extends far beyond TKAs. In shoulder arthroplasty, where setup

complexity and implant inventory can be a challenge, Lean and Lean Six Sigma logistics can streamline implant availability and reduce tray wastage similar to TKA. In high-turnover sports medicine procedures, such as anterior cruciate ligament (ACL) reconstruction, Lean and Lean Six Sigma can improve turnover times in the OR, standardise graft harvesting and preparation, significantly increasing the number of cases per day [17, 24]. Even in trauma surgeries, where predictability is usually low, Lean and Lean Six Sigma can be applied. By creating dedicated trauma pathways, the time-to theatre can be reduced, thereby improving mortality and morbidity [4, 26].

BRIDGING THE IMPLEMENTATION AND TECHNOLOGICAL GAPS

A common limitation in applying Lean models is implementation. Success depends on firm leadership commitment, cross-disciplinary participation (surgeons, anaesthetists, nurses and physiotherapists), reliable data systems and continuous performance feedback [20, 22, 25]. Barriers include resistance to change, lack of training and misalignment between surgical scheduling and ward-level resources [7, 19].

While evidence is growing, the current literature remains dominated by single-centre studies and pilot projects. Future prospective, multi-centre analyses should be conducted to validate these findings and define metrics for benchmarking efficiency alongside clinical outcomes. Lean is not a one-time intervention but an evolving culture of critical evaluation and adaptation.

POTENTIAL FOR ALGORITHMIC AND DIGITAL INTEGRATION

The next stage of Lean in arthroplasty will likely involve the integration of digital tools, predictive analytics, and registry data. Potential directions include:

- Integration of Lean workflows with AI-based scheduling and real-time resource forecasting (using algorithms to predict case duration based on patient BMI, surgeon, historical data and comorbidities to prevent under- or over-booking).
- Alignment with value-based reimbursement and registry benchmarking to quantify both cost and outcome efficiency.
- Extending Lean across the continuum of care, including prehabilitation, outpatient physiotherapy and telemonitoring.
- Continuous sustainability audits ensuring that improvements persist beyond initial implementation.

EXAMPLES OF POTENTIAL CLINICAL APPLICATIONS

To fully realise the potential of Lean, beyond isolated projects, their implementation should be illustrated with concrete, step-by-step examples:

1. Pre-operative Pathway Standardisation

- **Step 1:** Map the value stream from referral to discharge to identify bottlenecks, duplicate assessments and waiting times.
- **Step 2:** Implement standardised workflows, including DOSA and fast-track pathways.
- **Step 3:** Create predictable flow via structured preoperative planning (imaging, labs, anaesthesia clearance, physiotherapy scheduling).

2. Intra-operative Workflow and Logistics

- **Step 1:** Apply time benchmarks for operative steps (induction, positioning, incision, implantation, closure) to reduce variance.
- **Step 2:** Optimise instrument trays to reduce sterilisation workload and unnecessary material use.
- **Step 3:** Implement anticipatory logistics for revision TKA to ensure implant and vendor coordination, reducing valuable OR time.

3. Post-operative Recovery and Bed Utilisation

- **Step 1:** Implement protocols for early mobilisation and structured physiotherapy.
- **Step 2:** Eliminate waste by removing unnecessary postoperative lab testing and prolonged inpatient observation.
- **Step 3:** Use coordinated discharge planning to achieve shorter, predictable hospital stays.

LIMITATIONS AND THE HUMAN FACTOR: IS LEAN "MEAN"

The transition of Lean from manufacturing industries to the healthcare systems can be challenging. While rigid and obligatory adherence to standardised surgical durations can potentially compromise personalised care and increase the chance of medical malpractice, this reflects a flawed implementation rather than an intrinsic failure of Lean. Correctly applied, Lean aims to remove waste in order to facilitate patient–provider interaction and patient care. Unlike unstructured intuition, Lean offers a systematic frame work for identifying and eliminating inefficiencies. However, its utility depends on the context: while highly effective for reproducible procedures like TKA, it is less suitable for high acuity environments, where biological variabilities

cause necessary deviation from standard work. Efficiency should be viewed as a tool to optimise clinical capacities, patient care and never as a metric that supersedes clinical reasoning.

A CALL FOR CULTURAL TRANSFORMATION

The total knee arthroplasty pathway derives a paradigmatic example of how Lean management can reconcile surgical excellence with economic responsibility. By systematically mapping value streams, standardising workflows, and eliminating redundant steps, orthopaedic centres can deliver high-quality outcomes while preserving resources.

Clinical experience suggests that even modest process modifications—such as omitting drains, tourniquets, and unnecessary postoperative testing (e.g., routine coagulation profiles or electrolytes in uncomplicated recoveries)—can yield measurable benefits without jeopardising patient outcomes. Lean in TKA is not merely a management concept; it is a mindset of precision, accountability, and continuous improvement. It aligns naturally with the principles of precision orthopaedics, delivering the right care, for the right patient, at the right time - with optimal efficiency and sustainability.

CONFLICT OF INTEREST STATEMENT

MT Hirschmann: Consulting fees from Depuy Synthes and Symbios; Honoraria for Lectures and Support attending Meetings from Depuy Synthes, Symbios, and S&N; Participation on Advisory Board for Depuy Synthes; Leadership positions in KSSTA Journal, ESSKA, German Knee Society, and Personalised Arthroplasty Society. P. Sadoghi: Industry grants from DePuy Synthes, Johnson & Johnson, alphamed, and Medacta; Editorial Board Member for JOA, KSSTA, and Arthroscopy.

ETHICS STATEMENT

None declared.

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