The Economic Case for Implementing Automated Tissue Removal and Bone Milling Systems in Orthopedic Spine Procedures

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As healthcare facilities face increasing pressure to improve efficiency and patient outcomes while managing costs, it is essential to consider the economic implications of adopting advanced technologies. In the operating room, automation can streamline procedures, enhance precision, address workforce shortages, improve surgical outcomes, and reduce healthcare expenditures.[1] However, the short- and long-term clinical and economic benefits should be weighed against the initial investment and any ongoing maintenance costs.

BACKGROUND

Automated tissue removal and bone milling systems represent significant advancements in orthopedic spine procedures that involve preparing autologous bone grafts, considered the gold standard for bone repair because of their biocompatibility and regenerative properties.[2] Traditional methods for processing autologous bone involve manually removing soft tissue and milling the bone into usable particles – tasks that are labor-intensive, time-consuming, and prone to variability based on individual skill. These manual processes also pose safety risks, such as sharps injuries and hand fatigue. Automating autologous bone preparation presents a compelling opportunity to streamline

LEARNING OBJECTIVES

- Understand why it is important to consider the economic implications of adopting automated technologies in the operating room.
- Recognize the factors that impact the decision to invest in an automated tissue removal and bone milling system in orthopedic spine procedures.
- Compare the bone yield and quality outcomes between manual and automated bone processing methods and understand how these differences can impact surgical procedures and patient outcomes.
- Learn the potential impact of automated bone processing systems on reducing workplace injuries among surgical technologists.
- Discuss the role of automation in promoting standardization in the operating room and its effects on workflow efficiency, consistency of results, and overall surgical outcomes.
- Identify practical strategies for surgical technologists to advocate for automated equipment in their healthcare facilities.

the surgical technologist's (STs) workflow while maintaining consistency in the size and cleanliness of bone samples. It can also offer enhanced workplace safety by reducing sharps exposure and physical strain on surgical staff.

The use of a reusable power base (Bone Mill+) that drives automated tissue removal (Prep+ disposable cartridge) and automated milling (Bone Mill+ fine, medium, or large disposable blade cartridge) can transform these manual tasks into automated ones from start to finish. Prep+ mechanically removes soft tissue from extracted bone within a closed, see-through cartridge on a 10-minute run cycle. Cleaned bone is placed directly into Bone Mill+, which mills bone in an 8.4-second single pass into the surgeon's specified particulate size.[3]

With staffing shortages and surgical demands on the rise,[4] automated bone processing may offer a cost-effective solution to optimize efficiency, improve outcomes, and support the operating room (OR) team during orthopedic procedures. Understanding the economic factors involved in implementing such a system can contribute to informed decision-making that balances clinical excellence with fiscal responsibility, ultimately promoting more efficient and patient-centered orthopedic care.

SAVING TIME AND IMPROVING EFFICIENCY

Implementing automation in the OR can lead to more predictable case duration predictions and better OR time utilization, ultimately resulting in cost savings, improved surgical outcomes, and increased operational efficiency.[5]

Automated tissue removal and bone milling have been shown to significantly reduce manual processing time and improve overall efficiency in autologous bone graft procedures. In a study comparing automated bone stripping and milling to manual bone processing,[3] (Table 1) 16 experienced STs demonstrated a faster time to readiness resulting from the following:

- **Faster bone processing:** Automated bone cleaning consistently took 10 minutes, more than 2.5x faster than manual tissue removal, which required an average of 27 (±14) minutes.
- **Faster bone milling:** The automated system milled bone in just 8.4 seconds, more than 99.9x faster than manual milling, which took an average of 14 (±9) minutes.
- **Decreased total bone processing time:** Total bone processing time (cleaning and milling combined) was reduced from an average of 41 (±23) minutes for manual processing to 10.14 (±0.06) minutes for automated processing. This 75% reduction in total processing time can significantly impact overall procedure duration.

This study showed that with automation, surgeons could rely on a consistent time of 10 minutes to fully process up to 25 g of autologous bone while planning surgery and recoup up to 30 minutes per level of harvested bone preparation. This time savings can result in freeing valuable minutes per procedure to dedicate more time to instrument preparation, assisting the surgeon, or managing other aspects of patient care. Depending on the ST's manual processing speed, this can potentially free up 40 valuable minutes per procedure. Notably, half of the STs underestimated their manual bone processing time by approximately 14 minutes.

TABLE 1: MANUAL VERSUS AUTOMATED BONE PROCESSING TIME[3]

Method	Avg time (mins) plus standard deviation (mins)	Total processing time (time to readiness)
Manual bone cleaning	27 ±14	41 ±23
Manual bone milling	14 ±9	
Prep+ bone cleaning	10 ±0	10.14 ±0.06 p<0.0001

INCREASING BONE YIELD AND QUALITY

The quality and yield of autologous bone graft material can impact OR costs and surgical outcomes in orthopedic spine procedures. Efficient harvesting and processing of autologous bone not only affects procedure duration but also influences the need for supplementary bone graft materials and the development of potential complications.[7,8]

An automated tissue removal and bone milling system may offer significant advantages in bone yield and quality of cleaning compared to manual methods. The study of experienced STs demonstrated that automated processing resulted in 64% greater bone yield than manual processing within a

TABLE 2: MANUAL VERSUS AUTOMATED BONE YIELD DURING TISSUE REMOVAL/BONE CLEANING[3]		
	Manual cleaning	Automated cleaning
Bone yield measured after 10 minutes (the time of Prep+ run cycle)	Average 4 g of bone *(68% of scrub techs cleaned 32% of the total 25 g)*	25 g of bone *(for all samples)* Avg 64% more bone yield than manual cleaning p<0.0001
Additional manual tissue removal time needed to finish cleaning 25 g of porcine bone	50% of participants required 20 minutes more	0 mins

10-minute period.[3] While automated cleaning consistently recovered the entire 25 g bone sample, manual cleaning yielded only 4 g on average in 10 minutes. Furthermore, half of the STs required an additional 20 minutes of manual cleaning to recover the full 25 g sample (Table 2).

The quality of cleaning of the processed bone also improved with automation. Independent STs, who were blinded to whether the sample had undergone manual or automated bone cleaning, rated the cleanliness of automated samples 15% higher than manually processed bone on a 10-point scale. Notably, 33% of manually cleaned samples scored below 4.8, indicating inconsistent quality (Figure 1).

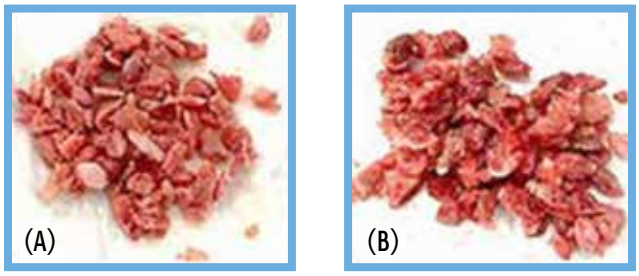

Figure 1.[3] *(A) Randomly selected automated sample (B) Randomly selected manual sample*

REDUCING LABOR COSTS

Automation can potentially reduce staffing requirements, minimize agency costs, and decrease costs associated with high turnover rates. Of the average cost-per-minute OR time, a significant portion – $13 to $14 – is attributed to wages and benefits.[6] With staffing shortages a top concern for American College of Healthcare Executives (ACHE) 2023 survey respondents9 and 51% and 56% of OR managers reporting rising turnover rates among STs and OR nurses, respectively, the challenging labor situation has led to increased reliance on agency and travel staff.[4]

High fatigue and burnout rates among healthcare workers impact productivity, job satisfaction, and turnover. One study reported that 65.6% of STs experience medium to high levels of work-related emotional exhaustion.[10] The physical demands of tasks such as manual bone processing may contribute to staff fatigue and potential burnout. In the aforementioned study comparing manual and automated bone processing, 100% of participants experienced hand fatigue during manual bone cleaning, and 75% reported fatigue during manual bone grinding[3] (Table 3). By reducing these physical strains through automation, healthcare facilities may see improvements in staff productivity and job satisfaction, decreasing turnover rates and associated costs.

With less time and resources spent on manual processes, staff can be reallocated to other critical tasks such as enhanced patient monitoring, improved team communication, and preparation for subsequent cases. In addition to improving efficiency, this reallocation may allow skilled OR staff to maintain better focus during critical phases of procedures and contribute to improved surgical outcomes.

MITIGATING THE RISK OF STAFF INJURIES

Workplace injuries are costly, both in terms of workers' compensation and lost productivity. By automating physical tasks that involve injury risks, healthcare organizations can potentially realize significant cost savings.[11] In the OR, implementing automated bone cleaning and

milling could be considered a preventive measure to help mitigate costs related to sharps injuries and carpal tunnel syndrome.

Sharps Injuries

The Centers for Disease Control and Prevention reports an estimated 385,000 sharps-related injuries annually among hospital-based healthcare personnel. However, at least half of these injuries go unreported. These injuries carry a high risk of exposure and transmission of blood-borne pathogens, including hepatitis B, hepatitis C, human immunodeficiency virus, and at least 20 other pathogens that can cause serious illness.[12] The direct and indirect costs borne by a healthcare facility may include the following:[13]

- Initial and follow-up laboratory testing and treatment
- Post-exposure prophylaxis or vaccine
- Workers' compensation and rehabilitation
- Time spent reporting the injury
- Time and wages diverted to receiving and providing exposure-related care
- Lost productivity

OR environments account for 42.8% of all sharps injuries, making it the highest-risk area in a hospital.[14] STs are at particular risk for percutaneous injury because they routinely handle sharp instruments, devices, and bone. One example is manually cleaning bone for autologous bone grafts. In the aforementioned study comparing traditional manual processing to an automated method during these procedures, half of the participants were observed to experience one or more glove punctures during manual bone cleaning versus no participants using the automated system. Notably, one-third of the study participants reported a previous sharps injury while manually cleaning or grinding bone[3] (Table 3).

Carpal Tunnel Syndrome

Because of the nature of their work, STs may also be at risk for developing carpal tunnel syndrome. Repetitive hand and wrist movements and forceful exertion in manual tasks are risk factors for this condition.[15] Manual bone processing is an arduous task involving multiple sharp tools and physically repetitive motions, which can cause hand fatigue and injury. In a survey of STs, 100% and 75% reported that they had experienced hand fatigue during manual bone cleaning and manual bone grinding, respectively (Table 3).

STs rely heavily on fine motor skills and manual dexterity to handle surgical instruments and supplies. Common carpal tunnel syndromes symptoms such as numbness, tingling, and weakness in the hands and fingers can affect their overall ability to perform their duties, resulting in time away from work and costs related to workers' compensation.

TABLE 3: PERSONAL SAFETY ASSESSMENT[3]

Past experiences with manual bone processing during self-reported survey[8]	
HAND FATIGUE	
Ever experienced hand fatigue while manual bone cleaning	100%
Ever experienced hand fatigue while manual bone grinding	75%
GLOVE PUNCTURE	
Ever experienced holes in gloves while manually cleaning bone	31%
Ever experienced holes in gloves while manually grinding bone	13%
INJURY	
Ever experienced injury while manual bone cleaning	31%
Ever experienced injury while manual bone grinding	19%

PROMOTING STANDARDIZATION

Standardization through automation may benefit ORs economically by addressing unnecessary clinical variation, which is a major driver of increased costs, such as extended OR time, in surgical procedures.[16]

Automated systems may provide more consistent

results across procedures, potentially leading to more predictable procedure times and improved resource allocation. Studies have shown that implementing standardized processes and digital support systems can reduce OR time by 6%-22% per case.[17] Additionally, automated workflow systems have demonstrated improvements in compliance rates, first-case on-time starts, and overall OR efficiency.[5]

A prime example of automation-led standardization in orthopedic spine procedures is automated tissue removal and bone milling, which has shown more consistent bone yields for grafting and significantly less variability in time to readiness (Tables 1 and 2). When asked to rate processed bone samples for cleanliness (free of excess soft tissue) on a scale of 1 to 10 (1 = very poor, 10 = excellent), STs blinded to the bone processing method (automated or manual) gave the automated samples a 15% higher quality cleanliness rating on average.[3]

More consistent results can help mitigate variations in individual ST skill and efficiency. Standardizing the bone graft preparation process with an automated system also helps streamline workflows and reduce the physical strain on surgical staff. This approach is particularly valuable when integrating new or rotating staff members because it minimizes the learning curve and potential for human error in a critical step of autologous bone graft procedures.

ADVOCATING FOR AUTOMATED EQUIPMENT

STs can effectively advocate for automated equipment purchases by leveraging their hands-on experience to provide valuable insights on the potential workflow improvements, efficiency gains, and safety enhancements that new technologies could offer. An online survey of STs conducted by Styker to determine what methods have proven successful in giving STs a voice in the decision- and purchase-making process revealed the following:[18]

- 73% brought convincing data or marketing materials to their OR managers
- 73% reported using interpersonal dynamics, friendship, and trust to influence equipment purchases
- 55% presented convincing data or peer-reviewed articles to surgeons
- 27% of STs participated on hospital value analysis committees

A combination of approaches, including collaborating with procurement teams and presenting convincing data or marketing materials to their OR managers, can empower STs to promote more efficient and patient-centered orthopedic care.

KEY TAKEWAYS

Evaluating the costs and benefits of automation

The up-front cost of implementing an automated tissue removal and bone milling system should be weighed against the potential long-term savings in terms of the following:

Efficiency and cost reduction

- Time and labor optimization: Automated systems can significantly reduce the time required for bone preparation, potentially allowing for more procedures to be performed and improving overall OR efficiency. This may also enable hospitals to optimize staffing levels or reallocate skilled personnel to other critical areas.

Ongoing operational considerations

- Total cost of ownership: Beyond the initial purchase, factors such as training requirements, maintenance costs, and operational expenses (including disposables, energy consumption, and specialized materials) contribute to the long-term financial impact.

Workflow integration and process optimization

- Adaptation and standardization: Successful implementation may require adjustments to current processes, which can initially impact efficiency but may lead to overall improvements in the long term. Automation can help standardize procedures across different surgeons and facilities, potentially leading to more consistent outcomes and quality control.

Labor and staff injury costs

- Mitigation of staffing shortages and injury risk: Automating labor-intensive tasks may help healthcare facilities address costs related to skilled labor shortages, expensive agency staff, and staff turnover. Automating tissue removal and bone milling may also help mitigate costs stemming from sharps injuries and carpal tunnel syndrome caused by manual/traditional bone milling.

As healthcare facilities strive for both clinical excellence and cost-effectiveness, the adoption of an automated tissue removal and bone milling system in the OR may represent a strategic investment that aligns with these dual objectives.

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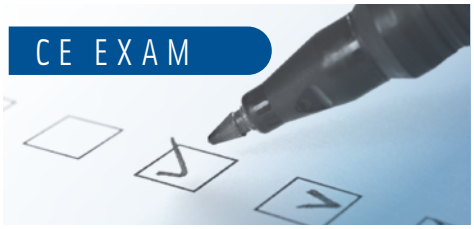

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The Economic Case for Implementing Automated Tissue Removal and Bone Milling Systems in Orthopedic Spine Procedures

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1. **Why is understanding the economic factors of implementing automated systems in the OR critical for healthcare facilities?**
   a. To ensure clinical excellence through improved surgical outcomes and enhanced patient care
   b. To maintain fiscal responsibility by evaluating short and long-term financial impacts
   c. To reduce equipment maintenance costs and staff training time
   d. Both a and b

2. **Which of the following factors is NOT mentioned as impacting the decision to invest in automated systems for orthopedic spine procedures?**
   a. Initial investment costs
   b. Long-term maintenance costs
   c. Surgeon preference for manual methods
   d. Clinical outcomes improvement

3. **Manual processes in the operating room promote standardization and help reduce variability in outcomes across different surgical technologists.**
   a. True
   b. False

4. **In the study comparing manual and automated bone processing, how much faster was the automated system in total bone processing time?**
   a. 2 times faster
   b. >2.5 times faster
   c. 5 times faster
   d. None of the above

5. **What capacity of autologous bone can be processed in 10 minutes with automation?**
   a. 60cc
   b. 90cc
   c. 120cc
   d. 150cc

6. **How much greater was the bone yield with automated processing compared to manual processing within a 10-minute period?**
   a. 32% greater
   b. 48% greater
   c. 64% greater
   d. 80% greater

7. **In a blinded evaluation of bone cleaning methods, what key finding emerged regarding automated processing?**
   a. The samples were processed more quickly but were of similar quality
   b. The automated samples showed consistently higher cleanliness ratings
   c. Manual processing provided more reliable cleaning results
   d. There was no significant difference in cleanliness between methods

8. **Which of the following workplace injuries may be reduced through the implementation of automated bone processing systems?**
   a. Sharps injuries
   b. Injuries resulting from repetitive strain
   c. Both a and b
   d. None of the above

9. **Which of the following is NOT listed as an economic benefit of automated bone processing?**
   a. Reduced need for surgical instruments
   b. Reduced processing time
   c. Enhanced workplace safety
   d. Improved bone yield

10. **Which combination of approaches were proven most successful for surgical technologists in influencing equipment purchase decisions?**
    a. Providing clinical data and participating in value analysis committees
    b. Presenting peer-reviewed articles and organizing staff petitions
    c. Bringing convincing data to OR managers and leveraging interpersonal relationships
    d. Submitting formal proposals and conducting cost analyses

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