

**Using Social Construction of Technology to Examine Stakeholder Influence in Limb
Salvage Surgery for Patients with Bone Sarcomas**

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By

Jack Pessaud

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISOR

Ben Laugelli, Department of Engineering and Society

Introduction

Orthopedic oncology has entered a new era, where limb salvage surgery has emerged as the dominant approach for treating bone sarcomas, challenging the long-standing reliance on amputation. Historically amputation was seen as the standard treatment, but this left patients having to deal with the physiological limitations as well as the psychological impediments that can occur when losing a limb (Kadam, 2013). However, recent advancements have shifted the tides within the orthopedic oncology field so that limb salvage surgery has become the treatment of choice for many patients diagnosed with bone sarcomas. Limb salvage surgery allows for tumor resection while maintaining a typical physical appearance and a near-typical function (Robert et al., 2010). Despite the advancements in limb salvage, it is not completely understood why it has become the preferred method over amputation. If the proposed approach is adopted, it will help to deepen the understanding of how motives outside of purely clinical data influenced the rise of limb salvage surgery as the preferred method for bone sarcoma treatment over amputation. In what follows, I will demonstrate that limb salvage surgery does offer clear advantages over amputation leading to it being the dominant surgical treatment method due to its agreed-upon value from the primary stakeholders involved (patients, physicians, and industry) for patients diagnosed with the most common bone sarcomas (Osteosarcoma, Chondrosarcoma, and Ewing sarcoma). I will use the Social Construction of Technology which is a framework originally developed by Bijker and Pinch that argues social factors, like values, needs, or interpretations from different social groups, shape technology as opposed to purely which design provides the greatest amount of technology or scientific progress (Pinch et al., 1987). By viewing the limb salvage surgery technology through the SCOT framework, I will show how the stakeholders affected the widespread adoption of limb salvage surgery over amputation.

Research from various institutions such as the National Cancer Database and MD Anderson Cancer Center as well as interviews of respected physicians from the field will show how the stakeholders agreed to limb salvage surgery being the primary method.

Background

Limb salvage surgery aims to preserve limb function and structure when amputation is a risk. It allows for stability to be restored with functional use while avoiding the physical, psychological, and socioeconomic impacts of amputation. Limb preservation has been sought after as an alternative to amputation since the 1960s. Through advances in microsurgery, external and internal fixation devices, endovascular procedure and negative pressure wound therapy, limb salvage surgery has become a viable surgery for many conditions such as trauma, cancer, chronic infections, peripheral vascular disease, and diabetic foot ulcers (Kadam, 2013). This paper will focus primarily on how limb salvage surgery is used for treatment as an alternative to amputation with three bone sarcomas: Osteosarcoma, Chondrosarcoma, and Ewing sarcoma. The vast majority of these solid tumors are found in the lower extremities with around a quarter in the upper extremities (Kadam, 2013). In recent years, limb salvage surgery has become the preferred method with more bone cancer patients receiving limb salvage surgery as opposed to amputation.

Literature Review

While several scholars have examined how limb salvage surgery compares to amputation for bone sarcoma patients by analyzing the direct health benefits and costs to the patient as well as the psychological benefits and costs, scholars have not adequately considered what other incentives could be pushing stakeholders to accept limb salvage surgery as the primary method for bone sarcoma removal outside of standard clinical data. Additionally, they do not properly address if there is disagreement amongst the different stakeholders over the preferred method but

assume that all stakeholders have the same priorities. A study conducted at the University of Texas M.D. Anderson Cancer Center aimed to assess the long-term psychosocial and functional outcomes of osteosarcoma survivors, comparing those who underwent limb-salvage surgery with those who underwent amputation. The data set consisted of 57 long-term (12-24 years since diagnosis) patients: 33 underwent limb-salvage surgery and the other 24 underwent amputation. The patients were assessed for functionality using the Toronto Extremity Salvage Score, quality of life using the QOL-Cancer Specific Scale, body image using the Amputee Body Image Scale, self-esteem using the Index of Self-Esteem, and social support using Sarason's Social Support Questionnaire (Robert et al., 2010).

Lower limb function was the main predictor for quality of life regardless of which surgical procedure was used. Body image concerns were significantly higher for those who had amputation after receiving a failed limb salvage procedure. Emotional well-being was tied to physical functionality but did not correlate with surgical methods. The paper concludes that surgical type does not have a significant impact on psychosocial outcomes and instead is reliant upon physical functionality (Robert et al., 2010). The results from this study helped to push the discussion over limb salvage surgery versus amputation for bone sarcomas to no longer just include oncology clinical data but also look at other factors like emotional health and quality of life. This was an important contribution to the scholarly discourse on what is viewed as the best surgical treatment for bone sarcomas by showing that stakeholders will not only view oncological data as the only value. Another study was conducted at Duke University Medical Center using data from the National Cancer Database. The study set out to assess survival outcomes of limb salvage surgery compared to amputation for patients with high-grade

osteosarcoma of the extremities. Patients were split into two groups: limb salvage surgery with 1,885 patients and amputation with 587 patients (Evans et al., 2020).

The study used Kaplan-Meier survival curves to assess overall survival and Cox proportional hazard models and propensity score matching to control for any confounding variables. The study found that patients undergoing amputation were more likely to be older, male, uninsured, and from lower-income areas. Additionally, they were found to be diagnosed with larger tumors, advanced-stage cancer, and more comorbidities (Evans et al., 2020). Patients undergoing limb salvage surgery were more likely to be younger, have smaller tumors, and have fewer comorbid conditions. Limb salvage surgery showed a significant survival advantage with a five-year survival rate of 67.8% for limb salvage and 53.7% for amputation. The study concluded that limb salvage surgery should be the preferred treatment for eligible patients but that inherent selection bias and clinical complexity may still influence outcomes (Evans et al., 2020). The discourse from this study brought into conversation how selection bias and non-clinical factors will impact stakeholders and the physical outcomes of survival. This helps to broaden the conversation from just oncology data and survival rates to further include how factors outside of the clinical setting can impact care and the view of what care is best.

Both of these studies expand the scope of how success should be viewed when looking at surgical options for bone sarcoma patients. By including psychosocial factors as well as demographics and inherent bias, the analysis can be expanded to not only viewing the somewhat narrowly defined views of physicians. These studies allowed for other variables outside of just clinical factors to be brought into the conversation. However, they do not fully address the complete range of stakeholders and their impacts on which surgical method is viewed as optimum. There is still a need to properly examine other variables outside of clinical outcomes

by bringing in other stakeholders. In my analysis, I will use the Social Construction of Technology to analyze if and how stakeholders came to an agreement on limb salvage surgery being preferable over amputation for patients with bone sarcomas by considering all stakeholders with a significant investment in the decision.

Conceptual Framework

My analysis of limb salvage surgery draws on the Social Construction of Technology (SCOT) framework which allows me to examine how different stakeholders' priorities led to limb salvage surgery being the ideal choice over amputation for bone sarcoma patients. Wiebe Bijker and Trevor Pinch developed SCOT in the 1980s arguing that technology development is influenced by social factors rather than being purely driven by technical or scientific advances. Bijker and Pinch focused on how human choices, cultural norms, and societal value shape the design and use of technology (Pinch et al., 1987). There are numerous key elements to SCOT. First, interpretive flexibility explains how different social groups can interpret and use the same piece of technology in various ways depending on their priorities and concerns as well as the customs and norms of their culture. Next, relevant social groups have varying needs for technology. The difference in the needs and use of technology will impact how the technology evolves and gets adopted. A technology can become closed when social debates and conflicts surrounding its design are resolved, and once closed, it becomes widely accepted without any significant changes to its form. Different groups may push for different design outcomes due to expectations for how technology should work among a specific group (Pinch et al., 1987).

Therefore, the success of a design is dependent upon the views of its necessary features from various stakeholders. In the analysis that follows, drawing on a SCOT framework, I will show that limb salvage surgery has become the dominant surgical method over amputation for

patients with bone sarcomas because of satisfying the needs and wants of the three key stakeholders: patients, physicians, and the medical device industry. Through analyzing what each stakeholder desires and how it is received through limb salvage surgery, it will be shown that the mutual agreement of the three primary stakeholders is what has led to limb salvage surgery being the prominent method for removing bone sarcoma tumors.

Analysis

Patients Have Enhanced Quality of life

In what follows, I show how limb salvage surgery has surpassed amputation as the primary surgical approach for removing solid bone sarcoma tumors by best satisfying patients' concerns over their quality of life after surgery. The most important quality of life improvement that patients need to be concerned about is the higher five-year survival rate for patients with limb-salvage surgery compared to amputation. The *Journal of Bone Oncology* published, in September 2020, Limb-salvage surgery offers better five-year survival rate than amputation in patients with limb osteosarcoma treated with neoadjuvant chemotherapy: A systematic review and meta-analysis. The study analyzed 13 retrospective studies involving 2,884 patients finding that patients undergoing limb salvage surgery had nearly double the odds of achieving a five-year overall survival compared to those who underwent amputation (Odds Ratio: 1.99, 95% CI: 1.35-2.93). However, there was no significant difference found in the five-year disease-free survival (DFS) for limb salvage surgery patients compared to amputation patients (Odds Ratio: 1.24, 95% CI: 0.55-2.79). This suggests that while overall survival did improve, disease recurrence was unchanged by the surgery type. Furthermore, while statistically insignificant, the odds of local recurrence were higher for patients treated with limb salvage surgery (Odds Ratio: 2.29, 95% CI: 0.95-5.53). This increased recurrence did not impact overall survival

(Papakonstantinou et al., 2020). The ultimate criterion for the quality of life is survival rate. In oncology, the five-year survival rate is the benchmark for lowering testing regimens and increasing confidence in disease remission (Penn Medicine, 2024). Therefore, the five-year survival rate is generally the highest priority for any patient diagnosed with a bone sarcoma. If a patient achieves the five-year survival, they can be confident in their treatment's success and have limited fear of recurrence. So, limb salvage surgery's significant correlation with increased five-year survival as well as decreased recurrence rates will have the greatest effect on patients' decision in limb salvage being the preferred treatment method. While the statistically insignificant increase in local recurrence with limb salvage surgery may cause some concern, it's important to note that logically this would be expected. After amputation, the location of the patient's tumor is entirely removed while with limb salvage surgery this location remains. So, the statistical insignificance of the local recurrence is a promising sign that this should not be of any concern to the patient. So, this suggests that bone sarcoma patients are most satisfied by limb salvage surgery because it satisfies their primary fears. While other quality-of-life variables are important, the most significant one of a five-year survival rate will be what the patients base their decision on for which surgical method is better.

However, this argument of quality of life hinges on a five-year survival rate being a quality data point for survival long term after bone sarcoma diagnosis and treatment. Some scholars argue that five-year survival does not accurately reflect the survival rate and that it is not a useful measure for cancer data analytics. A study in the *Asian Pacific Journal of Cancer Prevention* analyzed public data from the cancer registry from England and Wales using five-year survival, incidence, and mortality statistics. The study found that there was a lack of correlation between mortality and five-year survival. They argue that improvements in five-year

survival have resulted from better diagnostic imaging and information leading to earlier diagnosis which causes an increase in survival from diagnosis without any actual clinical improvement (Li et al., 2017). Mortality as a metric, however, does not fluctuate with earlier diagnosis. They are also less susceptible to variation from any additional confounding factors that are unimportant for clinical improvement (Li et al., 2017). However, this view fails to incorporate incidence rates into its analysis of the data. Frank R. Lichtenberg found in his writing for the National Bureau of Economic Research that when “incidence is controlled for, there is a highly significant correlation, in both the U.S. and Australia, between the change in 5-year survival for a specific tumor and the change in tumor-related mortality” (Lichtenberg, 2010). This is because cancers with great survival gains will also tend to see a rising incidence rate (Lichtenberg, 2010). This rising incidence rate can then neglect and hide survival gains seen within the patient population. While not perfect, five-year survival rates allow for an earlier understanding of treatment performance. If mortality rates were to be used solely, there could be a delay in data analysis since mortality is not subject to a certain time frame. Five-year survival rates allow for a relatively quick turnaround in data collection so that treatments may be analyzed, improved, and critiqued while staying on the cutting edge of technology. Therefore, while five-year survival rates have limitations, incorporating incidence rates into analysis strengthens their validity, making them a valuable tool for assessing treatment effectiveness in real time and facilitating continuous improvements in cancer care.

In addition to the physiological benefits of limb salvage surgery, there are also important psychosocial outcomes. The psychosocial impacts from limb salvage surgery cause the quality of life to increase for bone sarcoma patients leading to it being the better surgical option from the patient stakeholder perspective. The University of Texas MD Anderson Cancer Center studied

the impacts of limb salvage surgery versus amputation on psychosocial outcomes for osteosarcoma patients. The study found the greatest impact on emotional well-being was a failed limb salvage surgery that would lead to amputation of the limb. This caused patients to score significantly lower on the body image test. Additionally, emotional well-being was better for patients with better lower limb function (Robert et al., 2010). The body image test and emotional well-being are essential benchmarks for patients' quality of life. If certain procedures cause patients to have a lower body image or decreased emotional well-being, those procedures are not indicative of enhanced quality of life. Therefore, the MD Anderson Cancer Center study shows that quality of life is increased for patients with successful limb salvage surgery because of better psychosocial outcomes. This suggests that limb salvage patients would talk and share more actively about their surgery than amputation patients. These perspectives of former patients could impact current patients' views on their surgery as they are deciding which path they should take. By seeing former patients view themselves more positively, current patients could have an increased desire to replicate the positive self-esteem seen in limb salvage patients. While many of these outcomes between the surgeries remain similar, the effects on emotional well-being are significant enough to show that limb salvage surgery would be viewed by patient stakeholders as enhancing the quality of life.

Physicians Gain Prestige

Physicians view limb salvage surgery as the best design option for surgical intervention for patients with bone sarcomas because it satisfies the criteria of using the most advanced surgical techniques as well as a paradigm shift within the medical community. Zachary D. Burke MD is an orthopaedic oncologist at Cleveland Clinic and specializes in pediatric and adult sarcoma. Dr. Burke notes how there are complications with surgery for adolescents with

osteosarcoma. Specifically, that “kids are still growing. So, how do we account for future growth in a limb... How do we manage differences in limb length? Second, how do we ensure the durability of a limb implant or reconstruction” (Cleveland Clinic, 2024). Dr. Burke notes there are numerous concerns with patient bone reconstructions, the main one being infection. When a prosthesis “gets infected, it is a significant challenge to treat without taking it out [which] becomes another limb-threatening situation” (Cleveland Clinic, 2024). Dr. Burke sees a lot of future with limb salvage surgery, especially over alternatives like amputation because “all of these advancements are helping improve long-term outcomes for patients with sarcoma” (Cleveland Clinic, 2024). Dr. Burke represents the general view of the physician stakeholders when it comes to limb salvage versus amputation. Physicians see the numerous complications that can come with prosthetic implantation during limb salvage but are more convinced by its rewards and especially the future that is coming with limb salvage methods. Physicians want to be part of the future of medicine. They have a desire to always be on the cutting edge so that their patients can receive the most advanced treatment. This desire causes them to view limb salvage as a more tantalizing option when opposed to the more archaic form of surgery found in amputation. This excitement for future potentials with limb salvage surgery leads physicians to view it as a better treatment for bone sarcoma. Therefore, limb salvage surgery satisfies the desire of the physician stakeholders to have cutting-edge technology leading them to choose it over amputation.

Furthermore, physicians believe in a prestige associated with limb salvage surgery that is not apparent for amputation. This leads them to choose limb salvage as the preferred method in the field over amputation. Dr. L. Scott Levin is the Chair of the Department of Orthopedic Surgery and professor of surgery in Plastic Surgery at Penn Medicine. Dr. Levin coined the term

“orthoplastic” more than 30 years ago to reflect his desire for a blend of care between both orthopedics and plastic surgery for limb salvage surgeries. Dr. Levin mentions how they “work as a team—orthopedic surgeons, plastic surgeons, vascular surgeons, and radiologists—bringing together the best of Penn Medicine to salvage limbs. Other centers may not have the depth and breadth of talent and techniques that [they] offer” (Cole, 2021). Dr. Levin emphasizes the availability of his team, that they are “available 24/7, 365. So if you have a patient with an acute problem or a chronic problem... [they will] be [there] to help” (Cole, 2021). Dr. Levin’s view of his team and their role in the medical community shows the pride and prestige that physicians feel from its use. Physicians want to feel pride in what they do. They have ambition for their practices and methods to be at the top of their field and better than their counterparts. Since limb salvage surgery is a source of this pride for the physicians, it leads them to view it as a more appealing alternative to amputation which does not carry the same dignity and esteem. Dr. Levin puts his team above other medical centers for their cross-specialty approach that is found through limb-salvage surgery. This increased prestige and view of themselves leads physicians to prioritize limb salvage surgery as a better alternative to amputation. Therefore, physicians choose limb salvage surgery over amputation for bone sarcoma removal because of its cutting-edge technology and source of pride for their practice.

Industry Providers Gain Profits

The medical device industry chooses limb salvage as the preferred surgical method because it generates higher revenue and leads to continuous follow-up or revision surgeries. There are significant financial incentives for device manufacturers for limb salvage when compared to amputation leading them to choose limb salvage surgery as the best method. A study working with the Southern Arizona Limb Salvage Alliance (SALSA) program found

significant financial advantages for limb salvage surgery over amputation. The study showed increased revenue generation with the SALSA team generating a 59.6% increase in revenue from 2015 to 2019. Total annual work relative value units (wRVUs) nearly doubled from 2015 to 2019. Additionally, there were increased procedure numbers with 839 procedures performed in 2015 to 1,639 performed in 2019. The study also found that preventing amputations through limb salvage surgery also reduced the long-term economic burden on the healthcare systems (Patel et al., 2022). The results from this study show how limb salvage surgery not only improves clinical outcomes but offers substantial financial advantages to hospitals, healthcare providers, and patients. The medical device industry benefits from these increased revenue streams, higher surgical volumes, and enhanced contribution margins. Industry stakeholders are most concerned with making profits and so, will be inclined to prioritize the method that allows them to generate the most profits. The benefits brought by limb salvage surgery lead to greater profits for the manufacturers. Ultimately, the financial incentives and higher revenue potential associated with limb salvage surgery make it the preferred choice for the medical device industry, ensuring its dominance over amputation as the primary surgical method for bone sarcoma removal.

Conclusion

Limb salvage surgery has emerged as a transformative treatment for bone sarcomas by offering both functional and psychological benefits over amputation. Research shows there are improved survival rates and better quality of life for patients undergoing limb salvage surgery as opposed to amputation. The SCOT framework reveals that the widespread adoption of limb salvage surgery is due to consensus among key stakeholders: patients, physicians, and the medical industry. Patients prefer limb salvage due to its enhanced physical function, psychosocial outcomes, and increased survival rate. Physicians favor it for its advanced surgical

techniques and the prestige associated with its cutting-edge procedures. The medical industry supports limb salvage surgery due to the financial incentives associated with it. These findings are significant because they show common agreement amongst all stakeholders so that patients can be assured in their choice of limb salvage surgery over amputation and not fear ulterior motives from other stakeholders that could jeopardize or not align with their concerns and priorities. Further research should continue to explore how social, economic, and professional factors shape the adoption of new medical technologies, not only in bone sarcoma surgical treatments but also across a broader range of medical devices and techniques.

References

- Business Research Insights. (2025). *Limb salvage systems market size & growth [2033]*.
Businessresearchinsights.com.
<https://www.businessresearchinsights.com/market-reports/limb-salvage-systems-market-105233>
- Cleveland Clinic. (2024, March 6). *The latest in limb-sparing techniques for pediatric patients with sarcoma*.
<https://consultqd.clevelandclinic.org/the-latest-in-limb-sparing-techniques-for-pediatric-patients-with-sarcoma>
- Cole, M. (2021, October 18). *Lower extremity guidelines for salvage (LEGS): An interview with Penn Orthopaedics Chair L. Scott Levin*. Penn Medicine.
<https://www.pennmedicine.org/for-health-care-professionals/for-physicians/physician-education-and-resources/physician-interviews/2021/november/lower-extremity-guidelines-for-salvage-an-interview-with-penn-orthopaedics-chair-l-scott-levin>
- Evans, D. R., Lazarides, A. L., Visgauss, J. D., Somarelli, J. A., Blazer, D. G., Brigman, B. E., & Eward, W. C. (2020). Limb salvage versus amputation in patients with osteosarcoma of the extremities: an update in the modern era using the National Cancer Database. *BMC Cancer*, 20(1). <https://doi.org/10.1186/s12885-020-07502-z>
- Kadam, D. (2013). Limb salvage surgery. *Indian Journal of Plastic Surgery: Official Publication of the Association of Plastic Surgeons of India*, 46(2), 265–274.
<https://doi.org/10.4103/0970-0358.118603>
- Li, S. Q., Pan, X. F., Kashaf, M. S., Xue, Q. P., Luo, H. J., Wang, Y. Y., Wen, Y., & Yang, C. X. (2017). Five-year survival is not a useful measure for cancer control in the population: an

- analysis based on UK data. *Asian Pacific Journal of Cancer Prevention : APJCP*, 18(2), 571–576. <https://doi.org/10.22034/APJCP.2017.18.2.571>
- Lichtenberg, F. R. (2010). Are increasing 5-year survival rates evidence of success against cancer? A reexamination using data from the U.S. and Australia. *Forum for Health Economics & Policy*, 13(2). <https://doi.org/10.2202/1558-9544.1202>
- Papakonstantinou, E., Stamatopoulos, A., I Athanasiadis, D., Kenanidis, E., Potoupnis, M., Haidich, A.-B., & Tsiridis, E. (2020). Limb-salvage surgery offers better five-year survival rate than amputation in patients with limb osteosarcoma treated with neoadjuvant chemotherapy. A systematic review and meta-analysis. *Journal of Bone Oncology*, 25, 100319. <https://doi.org/10.1016/j.jbo.2020.100319>
- Patel, N., Tan, T.-W., Weinkauf, C., Rice, A. H., Rottman, A. M., Pappalardo, J., Goshima, K., & Zhou, W. (2022). Economic value of podiatry service in limb salvage alliance. *Journal of Vascular Surgery*, 75(1), 296–300. <https://doi.org/10.1016/j.jvs.2021.07.126>
- Penn Medicine. (2024). *Why the 5 year survival rate for cancer matters*. <https://www.pennmedicine.org/cancer/about/focus-on-cancer/2015/november/why-the-five-year-survival-rate-for-cancer-matters>
- Robert, R. S., Ottaviani, G., Huh, W. W., Palla, S., & Jaffe, N. (2010). Psychosocial and functional outcomes in long-term survivors of osteosarcoma: A comparison of limb-salvage surgery and amputation. *Pediatric Blood & Cancer*, 54(7), 990–999. <https://doi.org/10.1002/pbc.22419>