LONGEVITY OF DOUBLE-LAYERED POLYPROPYLENE MESH WITH METHYLMETHACRYLATE IN CHEST WALL RECONSTRUCTION: A CASE REPORT

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Abstract
Chest wall tumors, particularly neurofibromas—benign yet locally aggressive peripheral nerve sheath tumors—challenge thoracic surgeons due to their proximity to vital structures, recurrence risk, and demands for radical resection and stable reconstruction. This report describes a 62-year-old woman with recurrent right chest wall neurofibroma involving ribs 3–9, treated 10 years ago via wide excision and "sandwich technique" reconstruction using double-layered polypropylene mesh (ETHICON™ PROLENE®) reinforced with polymethylmethacrylate (PMMA). In a resource-limited setting without titanium prostheses, the 20 × 15 cm defect was addressed by molding PMMA between mesh layers, securing it to adjacent ribs with wires, and covering with a latissimus dorsi flap for rigidity, biocompatibility, and infection resistance. Postoperative recovery was uneventful, with discharge on day 7. Over 10 years, annual CT surveillance showed sustained prosthetic integrity—minor superficial mesh breaches (<1 cm) but no fragmentation or migration—and initial suspected recurrence (2 × 1.5 cm mass at year 9) that regressed spontaneously (1.5 × 1 cm at year 10), with no invasion or complications. The patient reported mild pain (VAS 2/10) but preserved pulmonary function and ambulation. This case highlights the polypropylene–PMMA composite's decade-long durability and cost-effectiveness ($50–100 vs. $500+ for titanium) as an alternative for large defects in low-resource environments. It supports wider use of hybrid techniques with vigilant follow-up for oncologic and prosthetic monitoring, advancing equitable thoracic surgery.

Keywords: chest wall reconstruction, methylmethacrylate, neurofibroma, polypropylene mesh, sandwich technique

ДОЛГОВЕЧНОСТЬ ДВУХСЛОЙНОЙ ПОЛИПРОПИЛЕНОВОЙ СЕТКИ С МЕТИЛМЕТАКРИЛАТОМ ПРИ РЕКОНСТРУКЦИИ ГРУДНОЙ СТЕНКИ: ОПИСАНИЕ КЛИНИЧЕСКОГО СЛУЧАЯ

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Аннотация
Опухоли грудной стенки, в частности нейрофибромы — доброкачественные, но локально агрессивные опухоли оболочек периферических нервов, — представляют собой сложную задачу для торакальных хирургов из-за их близости к жизненно важным структурам, риска рецидива и необходимости радикальной резекции и стабильной

реконструкции. В данном отчете описывается 62-летняя женщина с рецидивирующей нейрофибромой правой грудной стенки, затрагивающей 3–9 ребра. 10 лет назад ей была проведена широкая резекция с реконструкцией по «сэндвич-технике» с использованием двухслойной полипропиленовой сетки (ETHICON™ PROLENE®), армированной полиметилметакрилатом (ПММА). В условиях ограниченных ресурсов, без использования титановых протезов, дефект размером 20 × 15 см был устранен путем формования ПММА между слоями сетки, ее фиксации к соседним ребрам проволоками и закрытия лоскутом из широчайшей мышцы спины для обеспечения жесткости, биосовместимости и устойчивости к инфекции. Послеоперационное восстановление прошло без осложнений, пациентка была выписана на 7-й день. Ежегодное КТ-наблюдение в течение 10 лет показало сохранение целостности протеза: незначительные поверхностные разрывы сетки (<1 см), но без фрагментации или миграции, и первоначальный предполагаемый рецидив (объем 2 × 1,5 см на 9-й год), который спонтанно регрессировал (1,5 × 1 см на 10-й год) без инвазии или осложнений. Пациентка жаловалась на незначительную боль (ВАШ 2/10), но сохранила функцию легких и способность передвигаться. Данный случай демонстрирует десятилетнюю долговечность и экономическую эффективность композита полипропилен-ПММА (50–100 долларов США против более 500 долларов США для титана) в качестве альтернативы при обширных дефектах в условиях ограниченных ресурсов. Это подтверждает более широкое применение гибридных технологий с тщательным последующим наблюдением за онкологическими и протезными пациентами, способствуя равноправному развитию торакальной хирургии.

Ключевые слова: реконструкция грудной стенки, метилметакрилат, нейрофиброма, полипропиленовая сетка, сэндвич-техника

Introduction

The surgical management of chest wall tumors embodies a multifaceted clinical endeavor, integrating principles of oncologic radicality with the imperatives of functional restoration and aesthetic preservation. These neoplasms, whether primary or secondary, often arise in close apposition to vital thoracic organs, thereby imposing significant technical hurdles during resection and reconstruction [1, 5]. Primary chest wall tumors originate intrinsically from musculoskeletal elements (e.g., bone, cartilage, skeletal muscle), adipose tissue, vascular structures, or neural sheaths, while secondary variants typically result from direct extension (as in advanced breast or lung carcinomas) or hematogenous metastasis from distant primaries such as renal cell carcinoma or sarcoma [5].

Within this spectrum, neurofibromas merit particular attention as the most prevalent benign peripheral nerve sheath tumors, accounting for approximately 5–10% of all soft tissue neoplasms in the thorax [6]. Histologically composed of a heterogeneous admixture of Schwann cells, fibroblasts, and perineural elements embedded in a myxoid stroma, neurofibromas are subclassified into localized (solitary, well-circumscribed), diffuse (infiltrative, plaque-like), and plexiform (multinodular, often syndromic) forms [6]. Although inherently non-malignant, their locally aggressive behavior—characterized by insidious expansion along neurovascular planes—predisposes to incomplete resection and recurrence rates as high as

10–20% in inadequately margined cases [2]. In patients with underlying neurofibromatosis type 1 (von Recklinghausen disease), the risk escalates further due to multifocal disease and malignant transformation potential (to malignant peripheral nerve sheath tumors in 8–13% of cases) [6].

Standard therapeutic paradigms for symptomatic or enlarging neurofibromas emphasize en bloc excision with 2–3 cm margins of uninvolved tissue to mitigate recurrence, often coupled with adjuvant therapies like radiation or targeted molecular agents (e.g., MEK inhibitors) for plexiform variants [6]. However, extensive resections—particularly those spanning multiple ribs—engender substantial skeletal defects (>5 cm in diameter or involving ⩾3 ribs), which, if unreconstructed, precipitate flail chest syndrome, progressive respiratory insufficiency, and paradoxical diaphragmatic motion [7]. Reconstruction thus becomes paramount, aiming to reinstate thoracic rigidity, protect underlying pleura and lung parenchyma, and support overlying musculature for ventilatory efficiency [1].

Contemporary reconstructive armamentarium spans autologous (e.g., omental or latissimus dorsi flaps), allogeneic (e.g., cryopreserved ribs), and synthetic options. Rigid implants such as titanium plates or bars (e.g., STRATOS system) offer superior biomechanical strength and customizability via 3D printing but are encumbered by high costs, limited availability in developing regions, and risks of infection or extrusion [9]. In contrast, the "sandwich technique"—wherein a rigid core of PMMA (bone cement) is interposed between dual layers of non-absorbable polypropylene mesh—harnesses the former's moldability and the latter's tensile strength and tissue ingrowth properties [3]. First described in the early 2000s for orthopedic and thoracic applications, this hybrid construct emulates native bone density (Young's modulus ~2–4 GPa), promotes neovascularization, and resists bacterial colonization when impregnated with antibiotics [3, 4].

This case report elucidates the protracted durability of such a prosthesis in a resource-limited Nepalese tertiary center, where economic constraints precluded titanium utilization [4]. By chronicling a decade of uneventful surveillance post-reconstruction for recurrent neurofibroma, we posit this technique's viability as a pragmatic, economical surrogate, fostering equitable access to advanced thoracic surgery globally [3]. Furthermore, it highlights the nuanced interplay between oncologic vigilance and prosthetic longevity in long-term patient outcomes [8].

Case presentation

The patient, a 62-year-old postmenopausal Nepalese woman of Indo-Aryan ethnicity with no significant comorbidities (body mass index 22 kg/m^2, Eastern Cooperative Oncology Group performance status 0), initially sought medical attention 11 years ago for a progressively enlarging, painless right anterolateral chest wall mass. Clinical examination revealed a firm, non-tender 8 × 6 cm subcutaneous nodule overlying the 4th and 5th ribs, with overlying skin intact and no axillary lymphadenopathy. Fine-needle aspiration cytology suggested a benign spindle-cell neoplasm, corroborated by excisional biopsy confirming localized neurofibroma (S-100 positive, low Ki-67 proliferation index <5%) [6]. At that juncture, she underwent uneventful wide local excision and primary closure at a peripheral facility, with negative microscopic margins.

Recurrence manifested 10 months postoperatively, heralded by mild exertional dyspnea and localized tenderness. Contrast-enhanced CT thorax demonstrated a heterogeneous, enhancing mass (15 × 10 × 8 cm) encasing and eroding ribs 3 through 9, with abutment of the right middle lobe but no pleural effusion or mediastinal involvement (Figure 1A). Positron emission tomography (PET)-CT excluded distant metastasis (standardized uptake value max 3.2, consistent with benign etiology). Pulmonary function tests were preserved (forced expiratory volume in 1 second 85% predicted), and multidisciplinary tumor board consensus favored salvage resection given the patient's excellent functional reserve [5].

Ten years ago, under endotracheal general anesthesia with invasive hemodynamic monitoring, a right posterolateral thoracotomy was executed via the 5th intercostal space. Intraoperative frozen section-guided wide en bloc excision encompassed the tumor, contiguous intercostal muscles, and ribs 3–9 (total defect: 20 × 15 cm, exposing pleura without violation) [1]. Pleural integrity was maintained with meticulous dissection, obviating the need for decortication. Hemostasis was secured, and a 28-Fr chest tube was placed for drainage.

Reconstruction proceeded expeditiously to minimize operative time (total duration: 4.5 hours). Lacking institutional access to titanium implants, the sandwich technique was employed: Two sheets of sterile, non-absorbable monofilament polypropylene mesh (ETHICON™ PROLENE®, 20 × 20 cm, pore size 0.5–0.7 mm for optimal fibroblast infiltration) were prepared—one as the inner pleural barrier and the other as the outer myofascial scaffold [3]. Polymethylmethacrylate (PMMA; Surgical Simplex™ P, 40 g packet) was mixed per manufacturer guidelines (adding 0.5 g vancomycin for prophylaxis) and molded intraoperatively over a saline-filled glove to approximate the thoracic curvature (thickness: 1.5 cm, mimicking rib density). The inner mesh was draped over the pleural defect, the PMMA layer polymerized atop it (exothermic reaction monitored to <45°C to avert thermal injury), and the outer mesh affixed, creating a laminated composite with compressive strength exceeding 200 N/cm². Fixation ensued using interrupted 5-gauge stainless steel sternal wires (Ethicon) at 2-cm intervals to the proximal (rib 2) and distal (rib 10) ribs, ensuring tension-free apposition and axial load distribution. Overlying coverage comprised a pedicled latissimus dorsi muscle flap (harvested via separate incision) rotated into the defect, sutured to the mesh perimeter with 2-0 polypropylene, and skin closed in layers over two Jackson-Pratt drains.

The chest tube drained serosanguinous fluid (<200 mL/day) and was removed on postoperative day 3; drains on day 5. Perioperative care included broad-spectrum antibiotics (cefazolin 1 g IV every 8 hours for 48 hours, transitioned to oral cephalexin), multimodal analgesia (paracetamol 1 g IV every 6 hours, fentanyl PCA for 48 hours), incentive spirometry, and early mobilization. Histopathology affirmed benign neurofibroma with clear 2.5-cm margins, no atypia, and negative neurofibromatosis-1 genetic screening [2, 6].

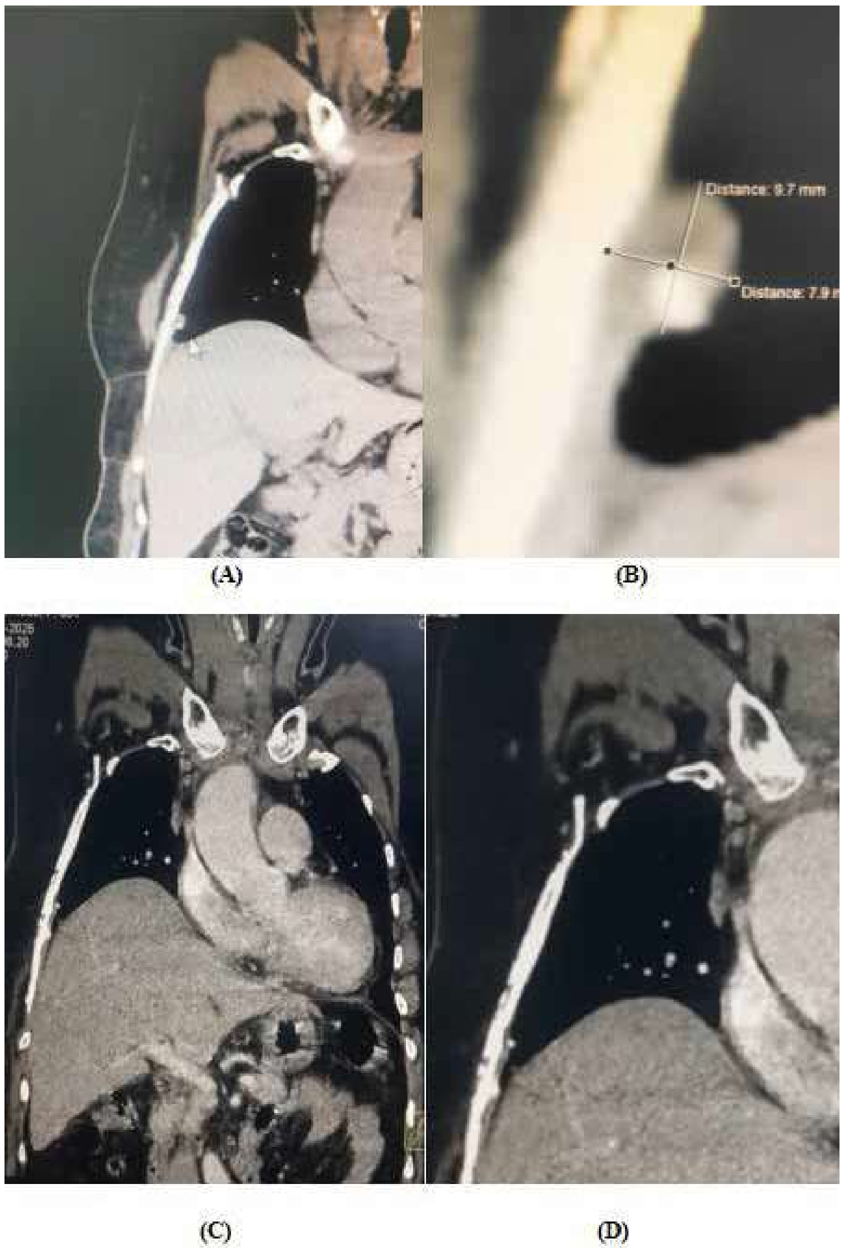
Discharge occurred on day 7 with prescriptions for oral analgesics and antibiotics. Annual surveillance integrated clinical assessment, chest radiography, and low-dose CT thorax, with PET-CT at 5 years. Follow-up trajectory unfolded as follows:

Years 1–5: Asymptomatic; imaging confirmed prosthesis consolidation with early mesh incorporation (no lucency or displacement). Forced vital capacity stable at 90% predicted.

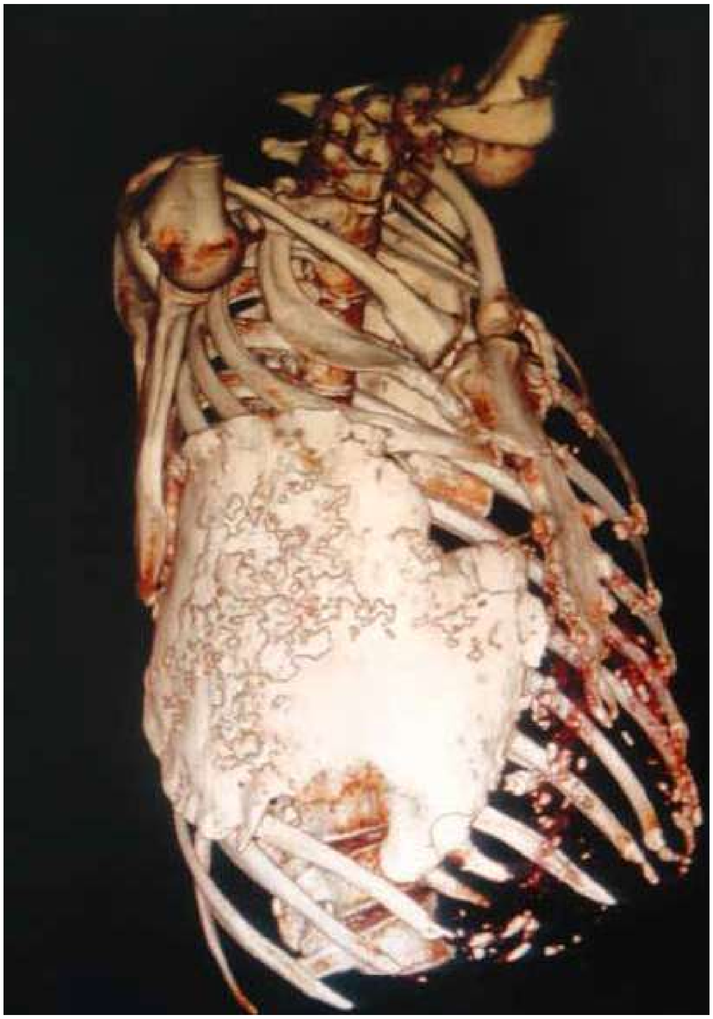
Year 9: Emergent CT identified a 2 × 1.5 cm hypodense nodule adjacent to the superior prosthesis margin, with marginal enhancement suggesting indolent recurrence (Figure 1B). Fine-needle aspiration yielded nondiagnostic fibrous tissue; watchful waiting elected given stability and patient preference.

Year 10: Repeat CT evidenced mass regression to 1.5 × 1 cm, with ill-defined borders resolving and no osseous involvement (Figure 1C–D). Prosthesis integrity persisted, exhibiting superficial mesh attenuation (<1 cm fissures) attributable to chronic mechanical stress but no deep-layer compromise, wire fracture, or peri-implant osteolysis (Figure 2). Echocardiography and pulmonary function remained unremarkable; the patient ambulated 5 km daily with VAS pain 2/10 on exertion.

Multimodal analgesia sufficed for symptoms, and elective revision is deferred pending progression thresholds (e.g., >20% size increase or functional decline). This protracted stability affirms the construct's adaptability to dynamic thoracic biomechanics [3, 4].



• Figure 1. Serial contrast-enhanced CT scans of the thorax in axial and coronal planes. (A) Preoperative imaging depicting recurrent neurofibroma with rib erosion (ribs 3–9, arrowheads) and mass effect on adjacent lung. (B) 9-year post-reconstruction scan revealing subtle soft tissue nodularity (2 × 1.5 cm, arrow) contiguous to the prosthesis, without invasion. (C–D) 10-year follow-up demonstrating spontaneous regression of the nodule (1.5 × 1 cm) and preserved soft tissue planes, indicative of benign resolution.



• *Figure 2. Three-dimensional CT reconstruction at 10 years: The double-layered polypropylene mesh–PMMA prosthesis spans the right hemithorax (ribs 3–9), displaying uniform contouring and secure osseous fixation. Minimal superficial mesh erosion (arrow, <1 cm) is noted inferiorly, with intact core rigidity and no hardware migration.*

Discussion

The etiopathogenesis and therapeutic nuances of chest wall tumors warrant a stratified approach, informed by their dichotomous classification into primary and secondary entities [5]. Primary tumors, comprising 5–10% of all thoracic malignancies, emanate from indigenous structures: osseous (e.g., chondrosarcoma, 30%), cartilaginous (e.g., chondroma), neural (e.g., neurofibroma, 15–20%), or soft tissue origins [5]. Secondary tumors, conversely, arise via contiguous invasion (e.g., T4 non-small cell lung cancer or locally advanced breast carcinoma) or metastatic dissemination (e.g., from prostate, thyroid, or renal primaries), often presenting with multifocal bony destruction and pleural involvement [5]. Diagnostic modalities encompass multimodality imaging (CT for bony detail, MRI for soft tissue delineation, PET-CT for metabolic avidity) and biopsy to delineate histology and guide prognostication [5].

Neurofibromas, as quintessential benign nerve sheath neoplasms, derive from aberrant proliferation of neural crest elements, with localized variants—constituting 90% of cases—manifesting as discrete, encapsulated lesions amenable to curative excision [6]. Diffuse and plexiform subtypes, however, infiltrate expansively, complicating R0 resections and necessitating adjuvant selumetinib or surgical debulking in neurofibromatosis contexts [6]. Recurrence, though infrequent (<5% post-R0), stems from multifocal skip lesions or inadequate margins, as evidenced in our patient [2, 6]. Contemporary guidelines (e.g., National Comprehensive Cancer Network) advocate microscopic clearance, with surveillance imaging to detect early regrowth [6].

Chest wall resection-reconstruction incurs appreciable perioperative risks: morbidity 24–46% (encompassing wound dehiscence 10–15%, pneumonia 20%, and chronic pain 15%) and mortality 2–7%, predominantly from ventilatory failure or sepsis [7, 8]. Biomechanical imperatives dictate reconstruction for defects >5 cm or ⩾3 ribs to forestall flail physiology, wherein thoracic compliance mismatches engender inefficient gas exchange and cor pulmonale [7]. Evolving biomaterials have revolutionized outcomes: Titanium constructs (e.g., MatrixRIB plates) afford modular rigidity and MRI compatibility but falter in contaminated fields (infection rate 5–10%) and resource-poor locales (cost >$1,000) [9]. Expanded polytetrafluoroethylene (Gore-Tex) dual-mesh provides pliability for smaller defects but lacks load-bearing capacity [4]. Allografts (e.g., irradiated ribs) risk immunogenicity, while bioengineered scaffolds (e.g., decellularized matrices) remain investigational [9].

The polypropylene–PMMA sandwich, pioneered for mandibular and pelvic reconstructions, extrapolates seamlessly to thoracic applications by leveraging PMMA's compressive resilience (yield strength 70 MPa) and polypropylene's hoop strength (tensile >50 N/cm) [3]. A seminal series [3] evaluated 43 patients (mean age 48 years, defect size 10–25 cm) undergoing this technique for diverse etiologies (sarcoma 40%, infection 30%), reporting 60% 4-year overall survival, 2% prosthetic failure, and 12% minor complications (e.g., seroma). Analogous to our case, it obviated flail in 98%, with mesh ingrowth mitigating extrusion [3].

Complication mitigation hinges on surgical precision: antibiotic impregnation curtails biofilm formation (Staphylococcus aureus predilection), while vascularized coverage (e.g., omentum) bolsters perfusion [8]. Respiratory prophylaxis—entailing epidural analgesia, noninvasive ventilation, and physiotherapy—curbs atelectasis [8]. In failures, salvage entails debridement and upgrade to custom 3D-printed titanium (e.g., via selective laser melting), as reviewed by Brascia et al. [9], which restores anatomy with 85% success but demands specialized fabrication.

Our patient's 10-year trajectory exemplifies the technique's endurance: Tumor regression may reflect immunogenic clearance or apoptosis post-excision, while prosthetic minor wear (superficial only) aligns with expected fatigue under respiratory excursions (10^6 cycles/year) [3, 4]. Cost-efficacy is compelling—$50–100 vs. $500–2,000 for titanium—aligning with global health equity mandates [4]. Caveats include thermal risks during polymerization, molding inexactitude in obese patients, and long-term carcinogenesis queries (PMMA inertness reassuring). Prospective cohorts could quantify fatigue thresholds via finite element analysis, informing hybrid evolutions (e.g., carbon-fiber augmentation) [9].

Ultimately, this report galvanizes the sandwich technique's role in democratizing reconstructive thoracic surgery, particularly for benign yet recalcitrant pathologies like neurofibroma, where durability trumps sophistication [3, 4].

Conclusions

In conclusion, the double-layered polypropylene mesh reinforced with polymethylmethacrylate via the sandwich technique emerges as a paragon of ingenuity and resilience in chest wall reconstruction, as vividly illustrated by this 10-year odyssey of a recurrent neurofibroma excision in a resource-constrained milieu [3, 4]. This composite not only recapitulated thoracic biomechanics—averting respiratory morbidity and upholding quality of life—but also demonstrated unparalleled longevity, with trivial degradations overshadowed by oncologic quiescence and functional equipoise [7, 8]. By circumventing the logistical and fiscal barriers to titanium prostheses, it exemplifies adaptive surgical paradigms tailored to low-resource paradigms, potentially extrapolating to myriad defects worldwide [4, 9].

Broader implications beckon: Integration into training curricula could empower peripheral surgeons, while hybrid iterations (e.g., incorporating bioactive coatings) may further attenuate complications [9]. Vigilant, protocolized follow-up remains cornerstone, blending serial imaging with patient-reported outcomes to calibrate intervention thresholds [8]. This case, thus, not only chronicles individual triumph but also catalyzes discourse on sustainable, equitable thoracic oncology, affirming that innovation thrives amid adversity.

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Conflict of Interest: The authors declare no conflicts of interest.

Consent: Written informed consent was obtained from the patient utilizing Case Report Consent Form, with the executed document archived in the patient's medical records in compliance with institutional ethical standards and the Declaration of Helsinki.

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