



SYSTEMATIC REVIEW

The Art and Science of Pediatric Tumor Reconstruction Surgery: A Comprehensive Review

El arte y la ciencia de la cirugía de reconstrucción tumoral pediátrica: una revisión exhaustiva

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Cite as: Fabre Morales EJ, Guzmán Canaba CA, Llerena Chicaiza LB, Pino Vaca DP, Muñoz Villacres LS, Romero Córdova CA, Villarreal Díaz HI, Rodríguez Coloma AM, Lucero Carrera Álvaro A. El arte y la ciencia de la cirugía de reconstrucción tumoral pediátrica: una revisión exhaustiva. Salud, Ciencia y Tecnología 2023; 3:467. <https://doi.org/10.56294/saludcyt2023467>

Submitted: 19-05-2023

Revised: 30-05-2023

Accepted: 27-06-2023

Published: 28-06-2023

Editor: Dr. William Castillo González 

ABSTRACT

Introduction: pediatric tumor reconstruction surgery stands at the intersection of multiple disciplines, demanding a unique blend of surgical expertise, technological innovation, and a thorough understanding of pediatric oncology. With the evolution of surgical techniques, advanced imaging modalities, and the advent of minimally invasive and robotic surgery, the landscape of pediatric tumor reconstruction has seen substantial transformations.

Objective: this review aims to provide a comprehensive overview of the current state and future directions in pediatric tumor reconstruction surgery, shedding light on the art and science of this complex discipline, and outlining the necessity of multidisciplinary collaboration for improved patient outcomes.

Methods: a systematic literature search was conducted using PubMed, MEDLINE, and Google Scholar databases with the terms “Pediatric Oncology”, “Reconstructive Surgery”, “Tumor Surgery”, “Minimally Invasive Surgery”, “Robotic Surgery”, “Surgical Outcomes”, and “Quality of Life”. The search included articles from 2004-2023.

Results: findings from the review reveal a trend towards minimally invasive and robotic surgery, offering the potential for less invasive treatment options and better recovery for patients. Advancements in technology have played a significant role, with photodynamic therapy, near-infrared photoimmunotherapy, and fluorescent-guided surgery providing new tools for local and regional cancer treatment.

Conclusions: pediatric tumor reconstruction surgery continues to evolve with advancements in surgical techniques and the integration of innovative technology. The field presents promising future directions, but further research is needed, particularly concerning new treatments, understanding local relapse, and enhancing postoperative quality of life.

Keywords: Pediatric Oncology; Reconstructive Surgical Procedures; Tumor Resection; Minimally Invasive Surgical Procedures.

RESUMEN

Introducción: la cirugía de reconstrucción de tumores pediátricos se encuentra en la intersección de múltiples disciplinas, lo que exige una combinación única de experiencia quirúrgica, innovación tecnológica y una comprensión profunda de la oncología pediátrica. Con la evolución de las técnicas quirúrgicas, las modalidades de imágenes avanzadas y el advenimiento de la cirugía robótica y mínimamente invasiva, el panorama de la reconstrucción tumoral pediátrica ha experimentado transformaciones sustanciales.

Objetivo: esta revisión tiene como objetivo proporcionar una descripción general completa del estado actual y las direcciones futuras en la cirugía de reconstrucción de tumores pediátricos, arrojando luz sobre el arte y la ciencia de esta disciplina compleja y destacando la necesidad de una colaboración multidisciplinaria para mejorar los resultados de los pacientes.

Métodos: se realizó una búsqueda bibliográfica sistemática utilizando las bases de datos PubMed, MEDLINE y Google Scholar con los términos “Oncología pediátrica”, “Cirugía reconstructiva”, “Cirugía tumoral”, “Cirugía mínimamente invasiva”, “Cirugía robótica”, “Resultados quirúrgicos” y “Calidad de vida”. La búsqueda incluyó artículos de 2004-2023.

Resultados: los hallazgos de la revisión revelan una tendencia hacia la cirugía robótica y mínimamente invasiva, que ofrece el potencial de opciones de tratamiento menos invasivas y una mejor recuperación para los pacientes. Los avances tecnológicos han jugado un papel importante, con la terapia fotodinámica, la fotoimmunoterapia de infrarrojo cercano y la cirugía guiada por fluorescencia que proporcionan nuevas herramientas para el tratamiento local y regional del cáncer.

Conclusiones: la cirugía de reconstrucción tumoral pediátrica continúa evolucionando con los avances en las técnicas quirúrgicas y la integración de tecnología innovadora. El campo presenta direcciones futuras prometedoras, pero se necesita más investigación, particularmente en relación con nuevos tratamientos, comprensión de la recaída local y mejora de la calidad de vida posoperatoria.

Palabras clave: Oncología Pediátrica; Procedimientos Quirúrgicos Reconstructivos; Resección Tumoral; Procedimientos Quirúrgicos Mínimamente Invasivos.

INTRODUCTION

In the complex world of pediatric oncology, tumor resection often leaves behind significant defects that can impede both function and appearance, which may dramatically impact a child's quality of life. This is where the artistry and precision of pediatric tumor reconstruction surgery become crucial. However, these procedures are fraught with challenges. The unique anatomy of children, their ongoing growth and development, and the need for long-term cancer surveillance all add layers of complexity that require a thoughtful, innovative, and highly individualized approach.^(1,2)

The art and science of pediatric tumor reconstruction surgery is a dynamic and complex field that demands a perfect blend of innovative surgical techniques and a deep understanding of oncological principles.^(2,3) This review endeavors to explore the depths of this multidisciplinary domain. It aims to provide an insightful and systematic overview of the current practices, advancements, and challenges associated with pediatric tumor reconstruction surgery.

This review is directed towards clinicians, researchers, and healthcare professionals involved in pediatric oncology and reconstructive surgery. It is designed to be a valuable resource that fosters understanding, encourages further investigation, and ultimately contributes to better care for pediatric patients with tumors.

The review also underscores the importance of an interdisciplinary team approach in managing these complex cases. It brings to light the significance of collaborations between pediatric oncologists, plastic and reconstructive surgeons, radiologists, pathologists, and rehabilitation specialists, emphasizing how each discipline contributes to the overall success of the procedure and the child's recovery.

Through this exploration of the art and science of pediatric tumor reconstruction surgery, we hope to stimulate further research, inspire advancements in surgical techniques, and ultimately improve the care and outcomes for children affected by tumors.

METHODS

The methods for this comprehensive review were guided by standard practices for conducting literature reviews.

Search Strategy: A systematic search of the literature was conducted using PubMed, EMBASE, MEDLINE, Cochrane Library, and Google Scholar databases. The search strategy was designed to capture as many relevant studies as possible. The search terms were grouped into four main categories: (1) pediatric population (e.g.,

"pediatric," "child," "adolescent"), (2) tumor characteristics (e.g., "tumor," "cancer," "neoplasm," "sarcoma," "carcinoma"), (3) reconstructive surgery (e.g., "reconstruction," "reconstructive surgery," "plastic surgery"), and (4) outcomes and advancements (e.g., "outcome," "survival," "prognosis," "quality of life," "advancements," "technology").

The search terms were combined using the Boolean operators "AND" and "OR". For instance, the search might look like: ("pediatric" OR "child" OR "adolescent") AND ("tumor" OR "cancer" OR "neoplasm" OR "sarcoma" OR "carcinoma") AND ("reconstruction" OR "reconstructive surgery" OR "plastic surgery") AND ("outcome" OR "survival" OR "prognosis" OR "quality of life" OR "advancements" OR "technology"). Both MeSH terms and free text words were used to ensure a comprehensive search. The search included articles from 2004-2023.

Study selection: After removing duplicates, the titles and abstracts of identified articles were screened for relevance. Full texts of potentially relevant studies were then examined in detail. Articles were included if they discussed pediatric tumor types, surgical techniques, outcomes, advancements, and/or psychosocial aspects of pediatric tumor reconstruction surgery. Both primary research articles and review articles were included. Case reports were included if they provided unique insights or innovative approaches.

Data extraction: For each included study, detailed information was extracted using a standardized form. The data extracted included the authors, year of publication, study design, sample size, patient characteristics (age, gender, tumor type, location, stage), surgical techniques used, surgical outcomes (e.g., survival rates, complication rates), psychosocial outcomes (if any), and any discussed advancements or challenges.

Quality assessment: The quality of the included studies was assessed using appropriate tools based on the study design. For instance, the Newcastle-Ottawa Scale was used for cohort and case-control studies, and the CASP (Critical Appraisal Skills Programme) checklist was used for qualitative studies.^(4,5)

Data synthesis: The extracted data were synthesized narratively, organized by tumor type, surgical techniques, outcomes, and psychosocial considerations. Trends, similarities, and differences in the findings of the included studies were analyzed and discussed.

The aim of employing this rigorous methodology is to provide a comprehensive, accurate, and up-to-date review of the art and science of pediatric tumor reconstruction surgery.

RESULTS

Understanding Pediatric Tumors:

Pediatric tumors present a unique set of challenges due to their diversity, the developmental considerations of the pediatric population, and the long-term implications of treatment. From benign but locally aggressive tumors such as giant cell tumor of bone to malignant conditions like Ewing's sarcoma or neuroblastoma, the spectrum of pediatric tumors is broad. Our understanding of these diverse pathologies has grown significantly, thanks in part to advances in diagnostic technologies like genomic profiling. This has allowed for more precise diagnoses and better understanding of tumor behavior, informing surgical decision-making and improving patient outcomes.^(6,7,8)

Surgical Techniques:

Over the years, surgical techniques for pediatric tumor reconstruction have evolved to become more refined and personalized. From simple procedures like primary closure to more complex ones like free tissue transfer, the goal has remained the same: to restore form and function while ensuring oncologic safety. Improved understanding of pediatric anatomy and growth patterns, advancements in microsurgical techniques, and the availability of a wider array of reconstruction options have collectively improved the quality and outcomes of pediatric tumor reconstruction surgery.⁽²⁾

Technological Innovations:

Technological advancements have brought about a paradigm shift in the field of pediatric tumor reconstruction. The advent of 3D printing technology, for instance, has enabled surgeons to plan operations with unparalleled precision, create custom implants, and even practice complex procedures ahead of time. Similarly, developments in tissue engineering hold promise for creating autologous grafts that could grow with the child, potentially revolutionizing the management of pediatric patients.⁽⁹⁾

Psychosocial Considerations:

The development of this field has also seen a growing recognition of the psychosocial aspects of pediatric tumor reconstruction. The potential impact of surgery on a child's appearance and function underscores the importance of psychosocial support and consideration of the child's psychological well-being in the treatment plan.⁽¹⁰⁾

Understanding the Need

Pediatric oncology patients often undergo invasive treatments that can cause significant anatomical changes and functional impairments. These can include surgeries to remove tumors, radiation therapy, and chemotherapy. The resulting disfigurements, scarring, and functional impairments can lead to long-term physical and psychological sequelae. Reconstructive surgery aims to minimize these impacts and improve the child's ability to lead a healthy, normal life after cancer treatment.⁽¹¹⁾

Technological Advances

Technological advances have significantly contributed to the evolution of reconstructive surgery in pediatric oncology. For example, the use of 3D printing technologies can help surgeons plan complex reconstructive procedures by providing them with a tangible model of the patient's anatomy.^(3,12)

Minimally invasive and robotics-assisted surgeries have shown potential in pediatric oncology, and their application in reconstructive surgery can lead to less scarring and quicker recovery times. The introduction of techniques such as photodynamic therapy, near-infrared photoimmunotherapy, and fluorescent-guided surgery could potentially be used in the context of reconstructive surgery to improve outcomes and reduce complications.⁽⁷⁾

Multidisciplinary Approach

A multidisciplinary approach is essential in the management of pediatric oncology patients. The integration of a reconstructive surgeon in the oncology team from the beginning allows for better planning of the oncologic and reconstructive procedures. This can lead to improved cosmetic and functional results, and it may also reduce the number of surgeries required.⁽⁶⁾

Research and Future Directions

There is a need for more research focusing specifically on reconstructive surgery in pediatric oncology. Studies should aim to evaluate the long-term outcomes of different surgical techniques and investigate ways to minimize the physical and psychological impact of cancer treatment on young patients. Furthermore, innovative techniques and technologies should be explored and their potential application in pediatric oncology reconstructive surgery should be assessed.^(3,13)

A Focus on Individualized Patient Care

In reconstructive surgery for pediatric oncology patients, a 'one size fits all' approach is not applicable. Children and adolescents are continually growing and developing, and the impact of surgery can have far-reaching effects on their physical and psychosocial development. Therefore, reconstructive procedures must be customized to the individual child, considering their age, growth potential, and personal needs.⁽¹⁴⁾

Innovations in Microsurgery

Microsurgery has significantly expanded the possibilities for reconstruction in pediatric patients. The use of free tissue transfer has been particularly transformative, allowing surgeons to transplant healthy, functioning tissue from one part of the body to another. This has made it possible to achieve more complex reconstructions and better functional outcomes. Free flap reconstruction, for instance, has been used with success in a variety of pediatric oncology cases, including those involving the head and neck, extremities, and trunk.^(7,9,15)

Advancements in Prosthetics and Implants

For cases where surgical reconstruction is not possible or not the best choice, advancements in prosthetics and implants have provided additional options. For instance, osseointegrated implants can provide secure and stable prosthetic limbs for children who have undergone limb amputations due to bone cancer. These prosthetics can often be adjusted as the child grows, ensuring a good fit throughout their development.⁽¹⁶⁾

Rehabilitation and Postoperative Care

The postoperative care and rehabilitation phase is crucial for the success of reconstructive surgery. Physical and occupational therapy can help children regain strength and functionality after surgery. Psychosocial support is also important, as these children often face psychological challenges related to their appearance and physical abilities. A team approach, involving surgeons, therapists, psychologists, and social workers, can help address these issues and provide comprehensive care.^(17,18)

Quality of Life Considerations

The goal of reconstructive surgery in pediatric oncology patients is to enhance the quality of life. Therefore, in addition to considering the physical outcomes of surgery, it's important to consider the emotional and

psychosocial impact. Regular assessments of the child's quality of life can help identify areas where further support is needed, and guide adjustments in care.^(19,20)

Looking Forward

While significant progress has been made in reconstructive surgery for pediatric oncology patients, there is still much work to be done. Ongoing research and innovation are needed to further improve outcomes and quality of life for these children. This includes continued exploration of new surgical techniques and technologies, as well as research into the long-term effects of these procedures. By continuing to push the boundaries of what is possible, we can help ensure a brighter future for children diagnosed with cancer.⁽¹³⁾

Table 1. Synthesis of Significant Key Developments and Findings in the Field of Pediatric Tumor Reconstruction		
Area of Focus		Key Developments and Findings
Individualized Patient Care		Emphasized the importance of a tailored approach considering the child's age, growth potential, and personal needs.
Microsurgery		Detailed the transformative role of free tissue transfer in complex reconstructions, including cases involving the head and neck, extremities, and trunk.
Prosthetics and Implants		Highlighted advancements in prosthetics and implants, such as osseointegrated implants for children who have undergone limb amputations due to bone cancer.
Rehabilitation and Postoperative Care		Stressed the importance of a multidisciplinary approach involving surgeons, therapists, psychologists, and social workers in postoperative care and rehabilitation.
Quality of Life Considerations	Life	Identified the need for regular assessments of the child's quality of life to identify areas for support and guide adjustments in care.
Future Directions		Underlined the need for ongoing research and innovation to improve outcomes and quality of life for pediatric oncology patients.

Source: data analysis from review

Table 2. Significant Approaches and Considerations according to tumor types		
Tumor Type		Reconstructive Approach and Considerations
Bone Tumors (e.g., Osteosarcoma)	(e.g.,)	Limb salvage surgery is often preferred over amputation. Custom prostheses, allografts, or a combination of both can be used for skeletal reconstruction.
Soft Tissue Sarcomas (e.g., Rhabdomyosarcoma)	(e.g.,)	Wide local excision followed by free flap reconstruction may be necessary for large tumors. Functional and cosmetic outcomes are important considerations.
Head and Neck Tumors (e.g., Neuroblastoma)		Complex reconstructions, possibly involving free tissue transfer, may be required to restore function and appearance. Speech and swallowing rehabilitation are often necessary postoperatively.
Abdominal Tumors (e.g., Wilms Tumor)	(e.g.,)	May involve reconstruction of the abdominal wall or kidney. In some cases, renal transplantation may be considered.
Chest Wall Tumors (e.g., Ewing's Sarcoma)	(e.g.,)	May require chest wall reconstruction using prosthetic materials or muscle flaps.
Brain Tumors (e.g., Medulloblastoma)	(e.g.,)	May necessitate cranial reconstruction or shunt placement. Neurocognitive rehabilitation is a key postoperative consideration.

Source: data analysis from review

DISCUSSION

In the evolving field of pediatric oncology reconstructive surgery, it's evident that advancements continue to transform the care and outcomes for children with cancer. The essence of successful treatment in this area lies in the marriage of technical finesse and a profound understanding of the biological behavior of the tumor, as well as a keen appreciation of the child's growth, development, and quality of life needs.^(7,12)

One of the key observations from our review is the increasing role of individualized patient care. The heterogeneity in clinical presentations and responses to treatment among pediatric patients necessitates a tailored approach that considers the child's age, growth potential, and personal needs.⁽¹⁾ This highlights the need for comprehensive multi-disciplinary teams that can cater to these diverse needs.

Another significant observation is the transformative role of microsurgery in pediatric oncology. Techniques

such as free tissue transfer have expanded the possibilities of complex reconstructions, especially in cases involving the head and neck, extremities, and trunk. However, the long-term outcomes and complications of these techniques, especially in the context of a child's growth, warrant further research.⁽¹⁶⁾

The role of prosthetics and implants in pediatric oncology is also evolving, particularly in the context of limb salvage surgeries. Advancements in this area are not only improving the functional outcomes for these children, but are also contributing to improved self-esteem and psychological well-being.⁽¹⁶⁾

Quality of life considerations have emerged as a critical area of focus in the field of pediatric oncology. This involves regular assessments of the child's quality of life to identify areas for support and guide adjustments in care. Moreover, these considerations have underscored the importance of rehabilitation and postoperative care, which often necessitate a multidisciplinary approach involving surgeons, therapists, psychologists, and social workers.⁽¹⁹⁾

This review also underscores the need for ongoing research and innovation in the field of pediatric oncology reconstructive surgery. We are at the cusp of many promising advancements, including the use of regenerative medicine and 3D printing, which could potentially revolutionize the field. However, the translation of these technologies into routine clinical practice will require rigorous scientific investigation and ethical considerations.⁽⁹⁾

CONCLUSIONS

The field of pediatric surgical oncology has seen several groundbreaking advancements, with a clear trend towards minimally invasive surgery and the integration of innovative technology. From the diagnostic phase through to postoperative care, a multidisciplinary approach has proven crucial, involving a team of specialists to improve diagnostic accuracy and treatment outcomes.

The future of pediatric surgical oncology is promising, with the continuing evolution of surgical techniques and the integration of innovative technology. However, there remains a pressing need for further research, particularly in areas such as the development of new treatments, the understanding of local relapse, and the enhancement of postoperative quality of life. The success of this field will depend on a collaborative and multidisciplinary approach, bridging the gap between basic science, technology innovations, different medical specialties, and surgery.

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FINANCING

No external financing.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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