OPEN

PRS GLOBAL OPEN

IDEAS AND INNOVATIONS

Craniofacial/Pediatric

3D Printing and Surgical Simulation for Management of Large and Giant Congenital Melanocytic Nevi

Santana S. Solomon, BS*
Thomas J. Sitzman, MD, MPH†

Summary: Tissue expansion with subsequent adjacent tissue transfer is often the preferred and sometimes the only option for reconstruction of large and giant congenital melanocytic nevi. Successful reconstruction with maximal efficiency and optimal aesthetic outcome requires careful planning of the tissue transfer, which itself requires careful selection of the tissue expander size and positioning. Unfortunately, there is little opportunity to gain experience in these skills due to the rarity of this condition. In situations where there is a rare condition that requires a complex technical procedure with much interoperative decision-making, surgical experience can be supplemented with the use of surgical simulation. In this article, we report on the use of three-dimensional patient imaging, three-dimensional printing, and surgical simulation for planning the reconstruction of large and giant congenital melanocytic nevi. We describe how this technology allows us to simulate multiple different approaches to expander placement and adjacent tissue transfer. We also describe how these simulations can be used to create cutting guides to guide final incision design and reduce intraoperative decision-making. Finally, we discuss how these models can be used to educate patients and families about the process and outcomes of nevus excision and reconstruction.
(Plast Reconstr Surg Glob Open 2023; 11:e5299; doi: 10.1097/GOX.0000000000005299; Published online 29 September 2023.)

INTRODUCTION

Large and giant congenital melanocytic nevi (CMN) are rare, with an incidence of one in 20,000 newborns.[1] The workhorse for reconstruction of these nevi is tissue expansion of adjacent unaffected skin followed by nevus excision and reconstruction with transfer of the pre-expanded tissue.[2–4] Unfortunately, the rarity of these nevi coupled with the unique distribution of each patient's nevus means that few surgeons will acquire sufficient experience to deftly manage all types of nevi. One approach to achieve better surgical outcomes for patients with large and giant CMN may be through enabling surgeons to better plan each patient's reconstruction.

Over the past two decades, surgical simulation has evolved as a tool to aid surgeons at all levels of training. A broad range of simulation methods is currently available, from simple simulators designed for practicing basic technical maneuvers to high-fidelity anatomically accurate simulators for mastering complex procedures.[5–7] In this report, we describe the use of patient-specific surgical simulation with printed three-dimensional (3D) models to aid in preoperative planning for patients with large or giant CMN. The approach utilizes 3D preoperative imaging, 3D printing of patient-specific models, and surgical simulation on these models to inform expander selection, expander placement, and flap design.

PATIENT AND METHODS

Patients with large and giant CMN are managed by a multidisciplinary team. Options for surgical management are discussed with each patient and caregiver. Those who express interest in surgical excision are provided education on potential surgical options and shown pre- and postoperative photographs of patients with similar nevi. Patients wishing to pursue expander-based reconstruction are offered the opportunity to receive individualized surgical models illustrating the anticipated surgical stages and results.

*From the *University of Arizona College of Medicine—Phoenix, Phoenix, Ariz.; and †Division of Plastic Surgery, Phoenix Children's Hospital, Phoenix, Ariz.*

Received for publication June 13, 2023; accepted August 16, 2023.

DOI: 10.1097/GOX.0000000000005299

Disclosure statements are at the end of this article, following the correspondence information.

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

Patients wishing to receive individualized surgical models are imaged with a 3D scanner (Sense 2 Scanner; 3D Systems, Inc, Rock Hill, S.C.) or a smartphone-based 3D camera (WIDAR; WOGO, Inc, Tokyo, Japan) to obtain a 3D point web/cluster. The images are imported into an editing software (MeshLab; Virtual Computing Lab, ISTI-CNR, Pisa, Italy). The nevus location is registered to the 3D framework using anatomic landmarks or topographical variations at the nevus edge. The digital image is trimmed to focus on the region containing the nevus and adjacent tissue to be expanded for reconstruction.

Within the 3D modeling software, the anticipated tissue expander is created as a 3D shape using the manufacturer's measurements at full expansion. The expander is placed onto the digital model of the patient at the surgeon's preferred location, thereby creating a digital model of the patient postexpansion. The expanded model is printed, along with the baseline, pre-expansion model, using a 3D printer and plastic resin (Form3L; Formlabs, Boston, Mass.). The expanded model is then coated with silicone rubber (Dragon Skin FX-Pro; Smooth-On, Inc., Macungie, Pa.) to simulate the overlying skin, using tented resins and/or paints to mark the nevus location. In practice, multiple digital models and silicone skins are made simultaneously for the surgeon to simulate alternative approaches.

To simulate the surgical procedure, the silicone skin made on the expanded model is transferred to the pre-expansion model. Surgery is then performed on the model, with incision and transposition of the skin flaps, excision of the nevus, and securing of the flaps. Surgery is repeated with additional models. The total surface area of the nevus that can be removed is compared between models, along with the final scar position and location of any remaining nevus. (**See figure, Supplementary Digital Content 1**, which demonstrates surgical simulation on various models, **http://links.lww.com/PRSGO/C786**.) Serial revisions to expander size and/or position are made as needed until, through direct comparison of each approach, a final surgical plan is created that removes the maximum amount of nevus and has the most ideal scar position.

Final models are then created showing expander position and size at full expansion and anticipated final surgical result (Fig. 1). Printed 3D models, or 3D images of these models, are presented to the patient and their caregivers for discussion and feedback. If the patient decides to proceed with surgery, full-size templates can be 3D printed for tissue expander positioning at the expander placement surgery and incision placement at the time of

Takeaways

Question: How can 3D printing and surgical simulation serve as techniques for the management of large and giant congenital melanocytic nevi (CMN)?

Findings: The rarity of CMN makes it difficult for surgeons to become experts in management. The use of 3D printing and surgical simulation allows for preoperative tissue expander placement and flap design to determine the best surgical plan for removal of the nevus with the patient and caregiver.

Meaning: Surgical simulation allows surgeons to test alternative surgical approaches, reduces intraoperative decision-making, and better educates patients and family members about anticipated surgical results.

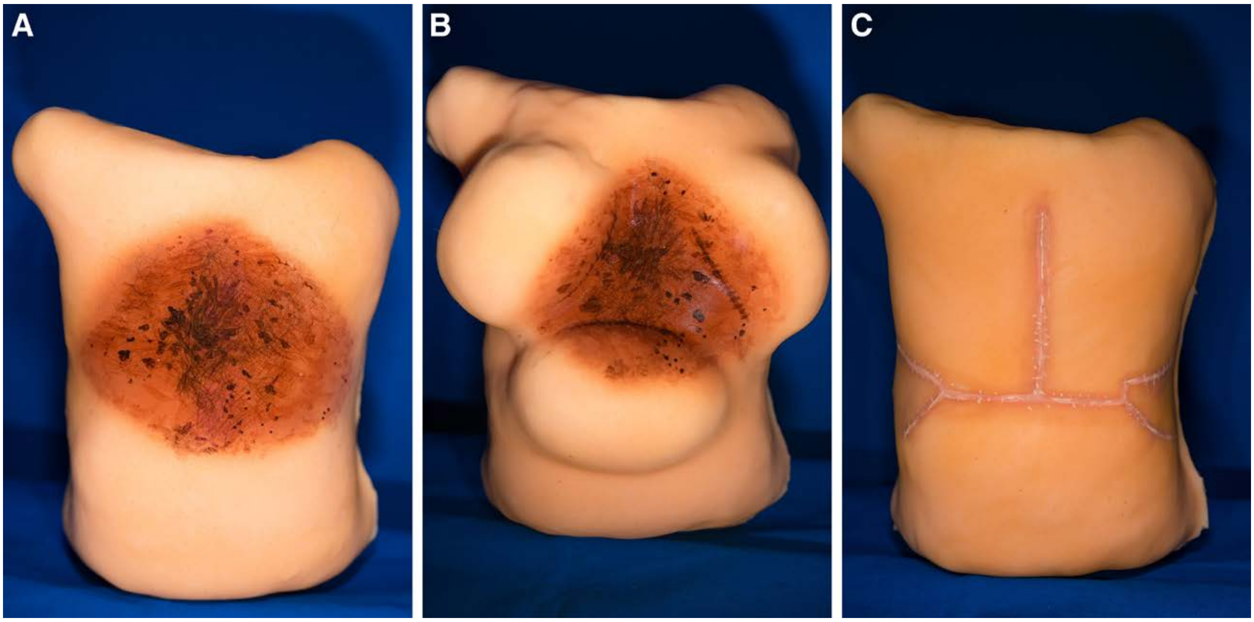

Fig. 1. A child who presented with giant CMN underwent tissue expander placement and surgical CMN removal informed by 3D model surgical simulation. A, Preoperative simulation of patient presentation. B, Model simulation of tissue expansion. C, Simulated reconstruction technique.

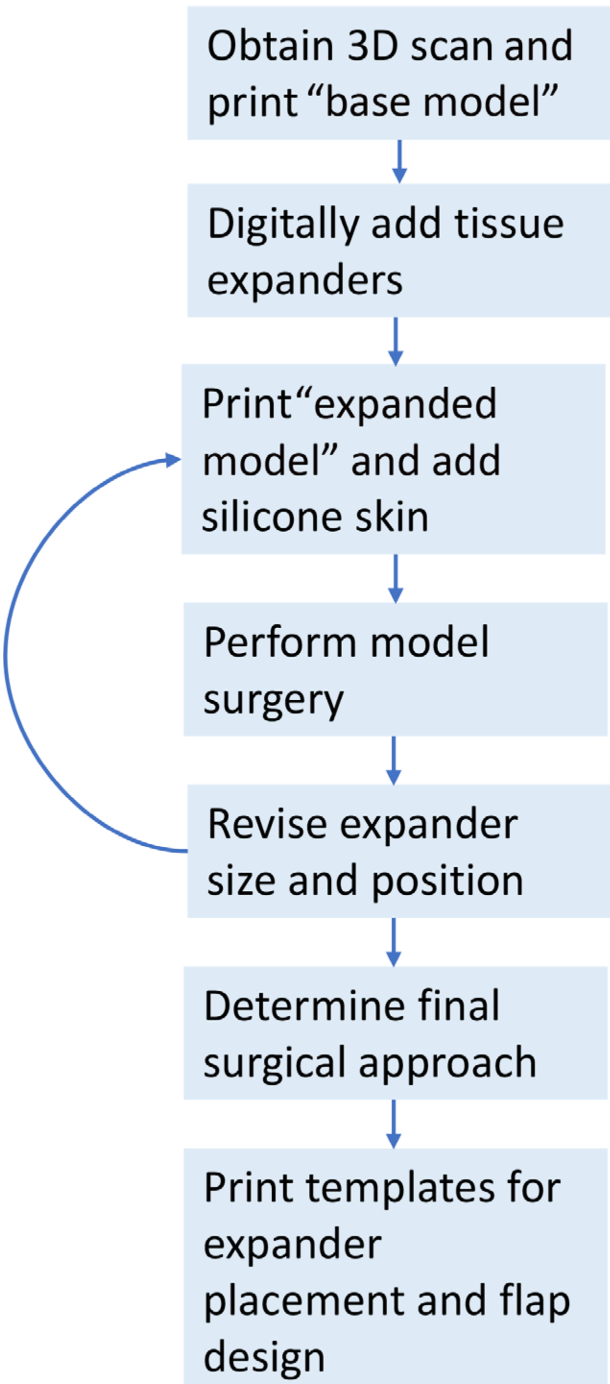

Fig. 2. 3D printing and simulation flow diagram.

expander removal and reconstruction. The overall process is outlined in Figure 2.

RESULTS

The case presented underwent three different 3D surgical simulations before a final surgical approach was determined (Fig. 1). The surgical simulation planning allowed for the removal of the entire CMN with a minimal number of operations and incisions.

DISCUSSION

We describe a novel combination of 3D imaging, digital modeling, and hands-on surgical simulation to facilitate preoperative planning for large or giant CMN excision. This use of 3D models for soft tissue transfer is an extension of prior work using patient-specific 3D models derived from computed tomography scans for surgical simulation of osteotomies in craniosynostosis and orthognathic surgery.[8]

Management of CMN can vary from observation to partial or completed surgical excision, with patient and caregiver preferences heavily influencing the approach taken.[9] The approach presented in this article enables surgeons to test different expander sizes and shapes,[10] different expander placement configurations, and different flap designs, allowing the surgeon to determine an optimal approach for each patient in advance of the operation. The approach also creates materials for patient and family education and feedback regarding the procedure. The opportunity for patients and families to see a simulated version of their future procedure facilitates meaningful conversations with the surgeon to express their concerns, understand the benefits of surgery, and visualize anticipated surgical outcomes.

This approach is not without limitations. The process requires an investment of both time and resources. Further, the benefits may diminish as a surgeon gains experience.

CONCLUSIONS

The rarity of giant CMN and limited individual experiences in the surgical management of the condition make preoperative planning difficult for surgeons of all skill levels. Surgical simulation, as presented here, allows surgeons to test alternative surgical approaches, reduces intraoperative decision-making, and educates patients and family members about anticipated surgical results.

Santana S. Solomon, BS
University of Arizona College of Medicine—Phoenix
475 N 5th Street
Phoenix, AZ, 85004
E-mail: sssolomon@arizona.edu

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

ACKNOWLEDGMENTS

The authors acknowledge Katharine Hanlon and Matthew Batie, who assisted in developing the methods and producing the models described herein.

REFERENCES

1. Castilla EE, Dutra MDG, Orioli-Parreiras IM. Epidemiology of congenital pigmented naevi: I. Incidence rates and relative frequencies. *Br J Dermatol*. 1981;104:307–315.
2. Kryger ZB, Bauer BS. Surgical management of large and giant congenital pigmented nevi of the lower extremity. *Plast Reconstr Surg*. 2008;121:1674–1684.

3. Bauer BS, Margulis A. The expanded transposition flap: shifting paradigms based on experience gained from two decades of pediatric tissue expansion. *Plast Reconstr Surg*. 2004;114:98–106.
4. Adler N, Elia J, Billig A, et al. Complications of nonbreast tissue expansion: 9 years experience with 44 adult patients and 119 pediatric patients. *J Pediatr Surg*. 2015;50:1513–1516.
5. Kazan R, Cyr S, Hemmerling TM, et al. The evolution of surgical simulation: the current state and future avenues for plastic surgery education. *Plast Reconstr Surg*. 2017;139:533e–543e.
6. Cheng H, Podolsky DJ, Fisher DM, et al. Teaching palatoplasty using a high-fidelity cleft palate simulator. *Plastic Reconstr Surg*. 2018;141:91e–98e.
7. Farrell DA, Miller TJ, Chambers JR, et al. Three-dimensionally–printed hand surgical simulator for resident training. *Plastic Reconstr Surg*. 2020;146:1100–1102.
8. Lobb DC, Cottler P, Dart D, et al. The use of patient-specific three-dimensional printed surgical models enhances plastic surgery resident education in craniofacial surgery. *J Craniofac Surg*. 2019;30:339–341.
9. Mosa A, Ho ES, Heinelt M, et al. Management of congenital melanocytic nevi in the plastic surgery clinic: families' expectations and their persistent concern about malignancy. *Pediatr Dermatol*. 2019;36:876–881.
10. Durgun M, Aksam E. Choosing the right rectangular expander and maximising the benefits from expanded tissue. *J Wound Care*. 2019;28:416–422.