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EDITORIAL (BY INVITATION)

Editorial: Low-cost patient-specific cranial implants for cranioplasty

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In this issue of Acta Neurochirurgica, Alice Xu, MD, et al. publish an article entitled "Towards Global Availability of Low-Cost, Patient-Specific Cranial Implants: Creation and Validation of Automated CranialRebuild Freeware Application." This paper explores the use of image-segmentation, modeling software, and the use of 3D printers to produce low-cost patient-specific cranial implants (PSCIs). According to the authors, this technique shows lower costs and may come as an effective solution for cranioplasty in low- and middle-income countries (LMICs) [7].

Craniofacial defects, especially post-decompressive craniectomy (DC), often result in esthetic and functional deficits. This often affects the patient's psyche and well-being. Cranioplasty (CP) is a neurosurgical procedure that aims to restore aesthesis, improve cerebrospinal fluid (CSF) dynamics, provide cerebral protection, and can facilitate neurological rehabilitation while enhancing recovery. [4] Preserved autologous bones are the favored option for filling small- to medium-size defects; for large cranial defects, CP with autologous bone is often challenging, and other various materials may be used. Several examples exist on the market, including metal or mesh plates, poly-methylmethacrylate (PMMA), hydroxyapatite ceramics, or carbon fiber reinforced polymer and, more recently, in the trends of CP material, polyether-ether-ketone (PEEK) and polyether-ketoneketone (PEKK) [5, 6].

Patient-specific implants are believed to be the optimal solution, but their use is limited or often impractical in most LMICs, where financial restrictions limit options for hermetically precise technology innovations. Medical technology has enabled unimagined advances, but often at great cost financially. In the circumstances where such technology is unavailable or unaffordable, innovations proliferate. A key part of the efforts to improve surgical provision globally includes providing affordable innovative solutions for LMICs. These medical innovations though require a complex mix of private and public sector inputs due to the ethical dimension of medical research, a rigorous regulatory framework, liability questions, cost-effectiveness, and practicability [1].

The challenge most LMIC-oriented innovations face is that they are designed in high-income countries (HICs) with limited LMIC contribution and implementation. Whereas it may appear that the benefits of an effective innovation developed in an HIC will translate on the ground, the reality is different. The 3D implants proposed by Xu et al. require on-the-ground evaluation in an LMIC settings. In fact, any of these countries do not have access to the required equipment and consumables, and the cost may therefore be wrongly assessed to be low [1, 6]. The significant health system-level differences between HICs and LMICs translate to unforeseen costs for patients, neurosurgery providers, and health systems. While it is true that the decreased cost of 3D printers and specific computer software has promoted adoption in some HICs, these technologies are still scarce in LMICs. The upfront costs of 3D printing adoption remain exorbitant for most LMIC hospitals. Hospital administrations' competing budgetary priorities prevent equipment acquisition and personnel capacity-building. In addition, LMIC hospital administrators and insurance providers are yet to define how to price and whether to cover these services. As a result, most care is covered out-of-pocket from patients.

Great innovations are user-centered and integrate the experiences of extreme users. By collaborating with LMIC colleagues from the get-go, frugal innovators can incorporate these considerations in their product design. For example, Zipline, a US-based autonomous drone delivery company, piloted its innovation in my home country (Rwanda). As of 2023, the company delivers more than 75% of blood products in Rwanda and has expanded to Ghana and Nigeria. Zipline's collaboration with the Rwandan government created buy-in which translated into greater adoption from early adopters (i.e., Rwandan, Ghanaian, and Nigerian governments) to an early majority (i.e., US-based users). In

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addition, their LMIC experience helped improve their minimum viable product and develop new use cases (i.e., vaccine delivery) [3]. In summary, early and intentional partnership of HIC disruptive innovators with LMIC colleagues is medically, operationally, and financially advantageous.

Traumatic brain injuries are the most prevalent neurosurgical disorder worldwide—affecting more than six million individuals each year. More than three-quarters of these individuals live in LMICs where access to timely care is limited. DC and CP are essential to the management of numerous patients. An innovation like the personalized patient implants by Xu et al. may directly improve patient outcomes in most LMICs. As such, this innovation should be supported and put in a position to succeed. In an era of decolonizing Global Neurosurgery, an evolving interdisciplinary subspecialty that aims to achieve global health equity for all people worldwide who require essential neurosurgical care, a field that has emerged and been driven by neurosurgeons in HICs seeking to serve the needs of people in LMICs, resolving a neurosurgical issue in a target LMIC, like patient-specific cranioplasty production, can certainly be partially addressed if through humanitarian efforts and initiatives to solution projects [2]. There is need for intentional collaboration with LMIC care providers, on ground assessment of proposed technologies from structural problems such as poverty, socioeconomic inequality, political instability, and lack of access to education or basic health services. Persistence of these barriers will otherwise limit the success of these undoubtedly genuine innovations.

Acknowledgements I congratulate Xu et al. on their innovation and look forward to seeing this invention achieve its potential.

References

1. Ashraf M, Choudhary N, Kamboh UA, Raza MA, Sultan KA, Ghulam N, Hussain SS, Ashraf N (2022) Early experience with patient-specific low-cost 3D-printed polymethylmethacrylate cranioplasty implants in a lower-middle-income-country: technical note and economic analysis. Surg Neurol Int 13:270. https://doi.org/10.25259/SNI_250_2022
2. Barthélemy EJ, Diouf SA, Silva ACV, Abu-Bonsrah N, de Souza IAS, Kanmounye US, Gabriel P, Sarpong K, Nduom EK, Lartigue JW, Esene I, Karekezi C (2023) Historical determinants of neurosurgical inequities in Africa and the African diaspora: a review and analysis of coloniality. Plos Glob Public Health. 3(2):e0001550. https://doi.org/10.1371/journal.pgph.0001550
3. Griffith EF, Schurer JM, Mawindo B, Kwibuka R, Turibyarive T, Amuguni JH (2023) The use of drones to deliver rift valley fever vaccines in Rwanda: perceptions and recommendations. Vaccines (Basel) 11(3):605. https://doi.org/10.3390/vaccines11030605
4. Iaccarino C, Kolias AG, Roumy LG, Fountas K, Adeleye AO (2020) Cranioplasty following decompressive craniectomy. Front Neurol 10:1357. https://doi.org/10.3389/fneur.2019.01357
5. Mele C, Bassetto A, Boetto V, Nardone A, Pingue V (2022) Impact of cranioplasty on rehabilitation course of patients with traumatic or hemorrhagic brain injury. Brain Sci 13(1):80. https://doi.org/10.3390/brainsci13010080
6. Tan ET, Ling JM, Dinesh SK (2016) The feasibility of producing patient-specific acrylic cranioplasty implants with a low-cost 3D printer. J Neurosurg 124(5):1531–1537. https://doi.org/10.3171/2015.5.JNS15119
7. Xu A, Venugopal V, Artual M et al (2023) Towards global availability of low-cost, patient-specific cranial implants: creation and validation of automated CranialRebuild freeware application Acta Neurochir (in press)