Ultrasonographic Assessment of Costochondral Cartilage for Microtia Reconstruction

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Commentary:

小耳症（microtia）是指耳廓结构发育不等程度之缺陷，发生率每万個新生兒約 0.83 - 17.4 例。小耳症的发生率在台灣粗估約三千之一至五千之一，其發生原因未明。大部份為單側患者，20-30% 為雙側患者。除了耳廓发育異常外，亦同時伴隨中耳聽骨鏈異常畸形與耳道的不完全發育，造成小耳症患者不等程度的傳導性聽障，尤其以耳道閉鎖（atresia）居多，耳道狹窄（stenosis）較為少見。除了外觀受到異樣眼光外，小耳患者還有戴眼鏡時的功能困擾與高發生率的情緒困擾疾病。研究指出兒童在 3-4 歲時就能觀察出身體外觀構造的差異，真正的考驗多發生於小學一年級，首次面臨同儕壓力或是霸凌而造成心理創傷。

當今小耳重建（Microtia Reconstruction）手術的發展，雖有人工材料（Medpor）的運用，但肋骨還是最多醫師使用的重建材料，肋骨的摘取一般建議是在 6-10 歲，主要是需考量摘取肋骨後可能造成胸壁畸形與肋骨質量是否足夠重建支架。過去的研究指出電腦斷層掃描（computed tomography, CT）可以用来評估患者肋骨是否適合摘取運用於小耳重建，但因費用與輻射問題而無法被廣泛使用。過去沒有在小耳重建前使用超音波（ultrasonogram）來評估肋軟骨是否適合摘取的研究，此研究以一位九歲小耳病例，詳細記錄術前第六根至第九根肋骨的橫向與縱向長度，術前的測量與術中比對，發現肋軟骨（costochondral cartilage）比肋骨體部（bony rib）具更多低超音波回音（hypoechoic），所以很容易辨識出硬軟肋骨結合（costochondral junction），而肋軟骨的橫向與縱向長度與術中測量相差不到 0.4 cm，準確度非常高，極具參考價值，終因原創度高而獲的評審青睞接受刊登。

關於小耳症患者幾歲適合接受小耳重建手術，關鍵在於肋骨取得的適當時機，如何在年紀與肋骨發育間取得平衡，影響重大。因為年紀太小太早進行手術恐有肋軟骨不夠的風險，年紀太大太晚進行手術可能會有肋骨鈣化或影響正常心理發展困擾。過去常用胸圍（chest wall circumference）做為參考，至少要 60cm 以上才能接受外耳重建，因為這代表有一定足夠的肋軟骨量可以摘取，但是個體的解剖構造差異，肥胖孩童，先前肋骨受傷等因素，容易造成胸圍參考性的不足。

相對於 CT，術前以超音波評估肋軟骨是否適合摘取運用於小耳重建，具有低成本、準確度高、較少輻射曝露及不需鎮静等優勢，對於醫療成本控制具相當吸引力。然而，這是單一個案報告，仍需大規模的研究病例來測試其實用性與其可能的盲點。
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INTRODUCTION

Microtia is a congenital abnormality of the auricle, which ranges in severity from mild structural defects to complete absence of the ear (anotia).1 The prevalence of microtia is estimated to be 0.83 to 17.4 per 10,000 births.2 Several studies have shown that individuals with microtia have difficulty with social integration and lack self-confidence.2-4 Microtia poses a functional challenge for children who require eyeglasses, and the prevalence of mood disorders such as depression, interpersonal sensitivity, social difficulties, hostility, and aggression increases with age among patients with unrepaired microtia.5 Studies suggest that children become aware of their physical differences between the ages of 3 and 4 years; however, psychological trauma is most likely to occur in the first grade, when children begin to socialize with a large group of peers for the first time.2,6

One of the mainstays of treatment for congenital microtia is reconstruction using autologous costochondral cartilage, first described by Tanzer6 and subsequently modified by Cronin, Brent and Nagata (Patel et al.).1 However, despite decreased morbidity and mortality over time, the procedure is still associated with complications including chest wall deformity, pneumothorax, hematoma, infection, overlying soft tissue necrosis, cartilage framework exposure, and graft resorption or loss.7 The risk of chest wall deformity and insufficient cartilage for auricular reconstruction in particular have been shown to increase dramatically if costochondral cartilage harvesting is done too early in a child’s development.8,9 Thompson et al. reported chest wall deformity rates of 33% and 8% for patients who underwent cartilage harvest between the ages of 2 to 3 and 6 to 12 years, respectively.10 Another study conducted by Ohara et al. reported chest wall deformity in 63.6% of patients who underwent cartilage harvest before 10 years of age and in 20% of patients who were older than 10 years at the time of harvest.9 Harvesting, however, is ideally done prior to full skeletal maturity,7 and early enough to minimize the psychosocial consequences of childhood ostracization.4 Most surgeons recommend microtia reconstruction with autogenous cartilage between the ages of 6 and 10 years.

Limited research has investigated the utility of computed tomography (CT) imaging to help guide the timing of surgery.9,11-15 Although these studies concluded that CT imaging may be useful in planning the timing of microtia reconstruction, the expense and exposure to ionizing radiation limit the widespread use of this imaging modality. Unlike CT imaging, ultrasonography is relatively inexpensive and does not expose patients to radiation. A few studies have reported using ultrasound as an effective diagnostic tool for evaluating costochondral cartilage deformities and traumatic rib fractures, as well as for assessing calcification patterns in costal cartilage prior to rib graft harvesting for revision rhinoplasty.16-18 However, to our knowledge, there have no reports in the literature that describe the use of ultrasound for determining the optimal timing of microtia reconstruction. In this report, we describe a novel application of ultrasonography to evaluate costochondral cartilage for use in microtia repair.

METHODS

A 9-year-old male with right-sided microtia was identified prior to stage I of microtia reconstruction. Preoperative ultrasonography of the chest wall was performed using an Acuson S3000 ultrasound system and a 9L4 high-resolution linear transducer (Siemens Medical Solutions USA, Malvern, PA). Transverse and longitudinal static and dynamic images of the sixth through ninth distal rib cartilages were obtained. Maximum transverse and longitudinal lengths of each individual cartilage were measured. When the length of the...
cartilage exceeded the length of the surface of the transducer, SieScape (Siemens Medical Solutions USA) panoramic real time images were acquired to improve anatomical information and to allow accurate measurements (Fig. 1). Intraoperatively, pictures were taken of the cartilaginous portion of the sixth through ninth ribs after harvest and prior to reconstruction, and rib dimensions were measured (Fig. 2). The rib dimensions obtained from the preoperative ultrasound were then compared with intraoperative rib measurements.

**RESULTS**

At the time of surgery, the patient was 9 years old and had a chest circumference that measured 69.5 cm. The costochondral cartilage was more hypoechoic than the bony rib, which allowed for visualization of the costochondral junction. The transverse and longitudinal costochondral cartilage lengths were clearly visualized and measured on ultrasonography, and these measurements were compared to the actual rib measurements (Table I). All of the ultrasound measurements were within 0.4 cm of the harvested specimen measurements.

**DISCUSSION**

In determining the optimal timing for microtia reconstruction, surgeons must find a balance between operating too early, thus risking insufficient costochondral cartilage available for harvest, and delaying the surgery too long, potentially resulting in adverse psychosocial consequences. Currently, most surgeons who perform autogenous rib cartilage ear reconstruction begin this procedure between the ages of 6 and 10 years of age, depending on which technique is employed. Brent reconstructions are performed in four stages, with the first stage typically starting when a child is 6 years old. Nagata reconstructions require only two stages and begin at approximately 10 years of age, when the ear is approximately adult-sized and the chest wall circumference at the xiphoid is at least 60 cm. Nagata reconstructions are performed later because they require significantly more cartilage for the antihelix, antitragal, and tragal complex, as well as an elevation piece for the second stage of the procedure. Although chest wall circumference can be a useful metric in some patients to determine the amount of costochondral cartilage available for harvest, its correlation to useable cartilage volume is not always reliable due to anatomical variability, childhood obesity, prior chest wall injury, and differences in overall nutritional status.

When performing a microtia reconstruction, it is not only the quantity of cartilage available for harvest that is important, but also the thickness of the rib cartilage used for the auricle framework. For the patient included in this study, measurements of cartilage thickness were not obtained intraoperatively, and thus we were unable to assess the accuracy of ultrasonography in measuring this dimension. However, because the longitudinal and transverse ultrasonographic measurements were similar to the actual measurements (all within 0.4 cm), we anticipate that the ultrasonographic measurements of cartilage thickness will be of similar accuracy.

We investigated the utility of ultrasonography in determining the optimal timing for microtia reconstruction...
and demonstrated that it can accurately determine the dimensions of costochondral cartilage. In comparison to preoperative CT imaging, ultrasound is very inexpensive and does not expose patients to radiation. It is also relatively quick and does not require sedation. At our institution, we have developed a protocol allowing ultrasound to be obtained the same day of the child’s preoperative appointment, providing significant convenience for families. At this preoperative appointment, we have started routinely collecting longitudinal, transverse, and thickness measurements of the costochondral cartilage.

For these reasons, high-resolution ultrasonography is a promising, novel approach to assess costochondral cartilage dimensions preoperatively. This noninvasive, low-risk modality may allow for a more accurate assessment of donor rib cartilage volume. Our group is currently assessing if this approach may translate to the ability to offer ear reconstruction earlier with greater assuredness that adequate donor cartilage is present in certain instances and avoid rare situations where there is an unexpected paucity of donor cartilage.

We are currently accruing a larger number of patients with ultrasonographic data at the time of the initial reconstructive surgery to determine optimal rib dimensions. Future research could investigate the interoperator variability with ultrasound assessment of costochondral cartilage.

**CONCLUSION**

Preoperative methods to accurately assess the amount of costochondral cartilage available for harvest in microtia reconstruction are lacking. We propose a low-cost, virtually risk-free preoperative technique for providing detailed rib dimensions. High-resolution ultrasonography has the potential to allow surgeons to evaluate rib dimensions prior to microtia reconstruction with greater accuracy, permitting safe and effective microtia repair earlier in a child’s development.

## BIBLIOGRAPHY