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# The use of intraoperative scalp expansion by Foley catheter in one-stage closure for scalp defect -review of eight cases-

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**Abstract**：Treatments for scalp reconstruction include simple closure by suturing, skin grafting, local flap, and free tissue transfer. In most cases, the optimal method is selected based on the defect size. Although simple suturing and local flaps are superior to other options for preserving hair-bearing qualities, careful selection should be made because advancements are limited.

Intraoperative scalp expansion using a balloon-type expander was introduced in the 1980s, by which scalp defects less than 4 to 4.5 cm in length could be closed in one stage without an extra incision or skin graft. However, the mechanism of skin stretching by intraoperative expansion is unclear, and stretchback, scalp necrosis, and alopecia have been reported as postoperative complications.

Intraoperative expansion was performed using Foley catheter balloons in eight cases of scalp defects. Patient characteristics, surgical techniques, postoperative courses, and complications were reviewed, along with relevant literature, which showed its usefulness even in a larger defect than that reported in combination with a local flap.

**Key words**：intraoperative expansion, foley catheter, scalp defect, local flap, skin graft

# Foley catheterを用いた術中組織拡張法にて１期的に創部閉鎖を得られた頭部皮膚欠損の８例

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**概　　要**：頭部有毛部の皮膚欠損創の治療は欠損の大きさによって縫縮，植皮術，局所皮弁術，遊離皮弁術などが選択される．植皮術，遊離皮弁術では移植部の質感の違いや禿頭など整容面でのデメリットが大きいため可能な限り縫縮や有毛部からの局所皮弁を適応したいが，被覆できる欠損の大きさに限りがある．

1980年代に入り術中にエキスパンダーを用いて皮膚を短時間で伸展させる術中組織拡張法が提唱された．簡便な方法であり文献上4-4.5㎝以下の欠損であれば植皮や皮膚の追加切開を行わずに創部を一期的に閉鎖することができるとされる．一方その伸展機序については明らかとなっておらず，後戻りの懸念や虚血による皮膚壊死や禿頭などの合併症が報告されている．最近ではエキスパンダーとしてfoley catheterを利用する報告が散見される．

今回我々は8例の頭部皮膚欠損の症例に対してfoley catheterによる術中組織拡張法を行った．文献上報告される適応よりも大きな創に対しても皮弁との組み合わせによって閉鎖可能であった．患者背景や原因，手術内容，経過，合併症の有無について文献的考察を加えて報告する．

**索引用語**：術中組織拡張術，フォーリーカテーテル，頭部皮膚欠損，局所皮弁術，植皮術

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## 【Introduction】

The goal of defect closure at hair-bearing sites is to minimize the tension of the wound and preserve the quality of appearance as possible[1]. Simple suturing and local flaps can be applied when the defect is small; however, skin graft and free flap transfer must be considered when the defect is large or normal adjacent skin is inadequate[2], although alopecia and mismatch of texture and color may occur. To overcome these demerits, scalp expansion was introduced as a method that utilizes the normal skin around the defect for closure[1,3]. Although a significant amount of tissue is gained by conventional expansion, it requires at least two surgeries for expander insertion and removal, with serial inflation for weeks to months in between, which causes a significant burden on the patient[1,3].

In contrast, one-stage intraoperative expansion permits skin stretching within minutes, though acquirable extra tissue is limited with an optimal indication of less than 4.0 to 4.5 cm in defect size[1,4-6]. Foley catheter balloons are commonly used for this technique[4-6,7].

Herein, we report eight cases in which intraoperative scalp expansion was performed, with detailed patient characteristics, surgical techniques, postoperative courses, and complications, along with a literature review.

## 【Patients and methods】

Between January 2021 and August 2024, eight patients underwent intraoperative scalp expansion to address scalp defects using a Foley catheter as a skin-stretching device. We recorded patient characteristics, primary causes, and areas of the scalp defect; increases in the area of the defect before and after the procedure, such as tumor resection or plate removal, in cases where both data were available; locations and layers of Foley catheter balloon placement; the number of catheters used and cycles of expansion; other treatments combined; postoperative days until discharge and stitch removal; postoperative complications within or after a month; and follow-up periods. Defect shapes were approximated as either elliptic or circular, and areas were calculated with the formula $1/4 \times \pi \times a \times b$, where a and b refer to the length of the major and minor axes, respectively.

### *Operation technique*

All surgeries were performed under general anesthesia. A 20-Fr, 30 mL volume Foley catheter balloon was used, with the tips distal to the balloon cut（Figure 1 a,

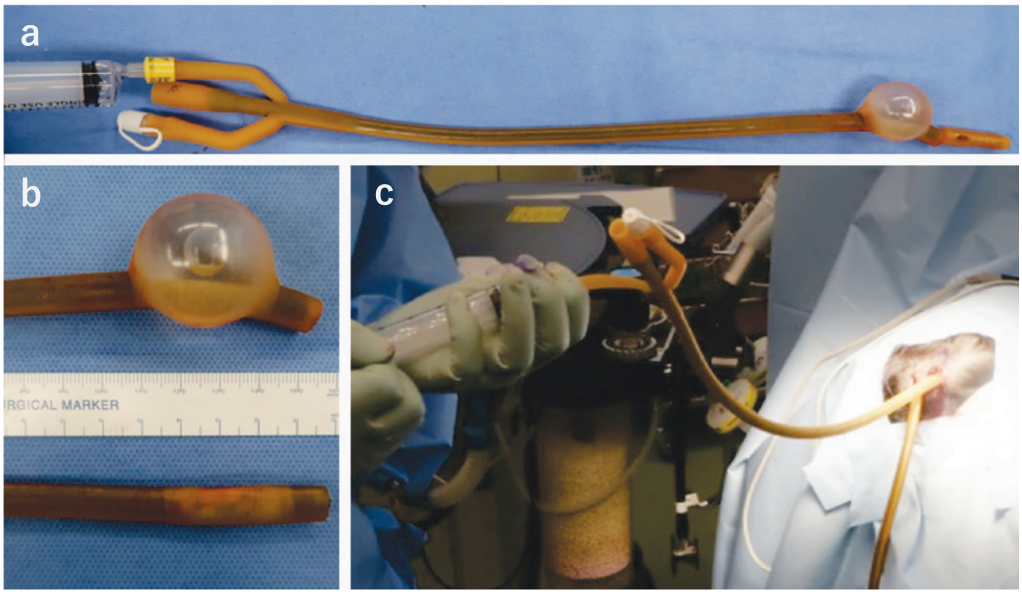


**Figure 1. The photographs show scalp expansion using a Foley catheter;** a: a 20-Fr Foley catheter is used as an expander, b: the distal end of the catheter is cut off to enable full insertion of the balloon under the scalp, c: inflation of the balloon with saline after its insertion.

b). More than one balloon was used for large defects or when the operative time was limited. Balloon placement sites were carefully considered. When using this method for future defects caused by tumor resection, small intralesional or marginal incisions are made to place the balloons before tumor resection to prevent extrusion of the expanding balloon. Balloons were placed in the subperiosteal or subgaleal layers of the planned site after undermining and creating a subcutaneous pocket through the initial incisions. The Foley catheter balloons were inflated in a staged manner using incremental amounts of saline (Figure 1 c). For example, in most cases, the first fill volume was 5 to 10 mL, followed by 10 to 50 mL for the second and third fill series. The amount of saline inflated was determined by skin tolerance as reflected by pallor and firmness. Each filling was sustained for 5 min, followed by deflation for 3 min. Two to three fills with different amounts of saline were often used in a cycle, and several cycles were repeated until the skin was stretched sufficiently for defect closure with minimal tension.

If the amount of adjacent normal skin was inadequate, a skin graft was added when a nonhair-bearing site was involved in the defect, and the expanded skin was used as a local flap when the defect size was large. The remaining skin was sutured layer-by-layer with a galeal approximation to achieve proper defect closure.

## 【Results】

Eight patients underwent an intraoperative expansion. The mean age was 32.1 (range, 8 to 79), and all patients were female. The most common cause was a benign skin tumor (four cases), followed by plate exposure (two cases), wound dehiscence and skin necrosis (one case). Locations included frontal and parietal in three cases and postauricular and occipital in one case. In the group of benign skin tumors, the mean lengths of the major and minor axis of the scalp defects were 1.93 and 2.40 cm, respectively, preoperatively, and expanded to 2.37 and 2.77 cm after tumor resection, resulting in an average area increase of 40.91% (from 3.84 to 5.50 $cm^2$). Whereas in the group of plate exposure, wound dehiscence, and skin necrosis, the mean length of the major and minor axis of the scalp defects were 2.25 and 4.05 cm, respectively, before the procedure and 3.40 and 5.15 cm after plate removal, extended incision, or debridement. The mean increase in area was 56.93% (from 9.07 to 15.31 $cm^2$). The positions of the balloons were subgaleal in four cases, subperiosteal in two cases, a combination of subgalel and subperiosteal in one case, and sub-superficial musculoaponeurotic system (SMAS) in one case.

The average number of balloons used and the sites of placement were 2.5 and 1.8, respectively. The mean number of expansion cycles was 2.5 cycles. A skin graft and local flap were used in one case each.

The mean number of postoperative days until discharge was 6.6 days and 11.4 days in stich removal. No postoperative alopecia or skin necrosis was observed.

The follow-up period was 5.4 months on average, excluding patients who were still under observation. All data are summarized in tables (Table 1, Table 2).

## 【Report of cases】

Cases were summarized by the causes of the defect.

***Benign skin tumor (Case1,2,6,8)***

Females aged 8 to 17 years had an unna or sebaceous nevus within 4 cm each in the parietal or postauricular area. Expansions were performed before nevus resection with balloons inserted below the galea in Cases 1, 6, and 8 (Figure 2 a, c, d). As the defect lay across the nonhair-bearing and hair-bearing areas in Case 2, a skin graft from the groin donor site was applied to the nonhair-bearing area (Figure 2 b). Expansion was performed below the SMAS in Case 2 to preserve the vascularity of the skin adjacent to the skin graft. Redness and small ulceration were observed postoperatively, which healed with ointments and did not affect the overall success of the procedure.

***Plate exposure (Case3, Case4)***

Cases 3 and 4 involved plate exposure after craniotomy in females aged 79 and 53 years, respectively (Figure 2 e). In Case 4, significant scarring and adhesions due to a history of multiple operations were observed, with an unidentifiable border of the galea and periosteum. More than four cycles of expansion were performed below

**Table 1. Case characteristics and expansion techniques**

| Case | Age/sex | Primary Cause | Location of the scalp defect | Preoperative defect size/Tumor size (cm)* | Defect size after the procedure (cm)* | Increase in the defect area% † (postoperative →after procedure (cm²)) | Location of the balloon placement | Balloon insertion layer | The number of balloons | The amount of saline used in each stage** in a cycle (mL) | The number of expansion cycles | Other treatments combined |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17/F | Tumor (Unna nevus) | Parietal | 1.1×2.3 | N/A | N/A | Parietal | Subgaleal | 2 | 10→30→40 | 2 | None |
| 2 | 17/F | Tumor (sebaceous nevus) | Postauricular | 2.4×3.5 | 3.1×4.0 | 47.78 (6.59→9.74) | Temporal | SubSMAS ¶ | 1 | 5→10 | 2 | Skin graft |
| 3 | 79/F | Plate exposure | Frontal | 1.0×2.1 | 1.3×2.3 | 42.42 (1.65→2.35) | Frontal | Subperiosteal | 1 | 10→20→30 | 3 | None |
| 4 | 53/F | Plate exposure | Frontal | N/A | N/A | N/A | Parietal | Subperiosteal | 2 | 35 | 4 | None |
| 5 | 50/F | Wound dehiscence | Frontal | N/A | 3.0×4.0 | N/A | Parietal, Occipital | Subgaleal | 2 | 10→30 | 4 | None |
| 6 | 8/F | Tumor (sebaceous nevus) | Parietal | 1.7×1.7 | 2.0×2.1 | 45.37 (2.27→3.30) | Parietal | Subgaleal | 2 | 10→15 | 1 | None |
| 7 | 22/F | Skin necrosis | Occipital | 3.5×6.0 | 5.5×8.0 | 71.43 (16.49→28.27) | Parietal, Temporal, Occipital | Subgaleal/Subperiosteal | 3 | 15→50 | 3 | Rotation flap |
| 8 | 11/F | Tumor (sebaceous nevus) | Parietal | 1.7×2.0 | 2.0×2.2 | 29.58 (2.67→3.46) | Parietal | Subgaleal | 2 | 5→15 | 1 | None |
| **Mean** | 32.1 | - | - | 2.25×4.05 ‡<br>1.93×2.40 § | 3.40×5.15 ‡<br>2.37×2.77 § | 56.93 ‡<br>40.91 § | - | - | 2.5 | - | 2.5 | - |

* Defect and tumor size before and after the procedure are described as minor axis×major axis (cm).
† Increase in the size is calculated as area = 1/4×π×major axis×minor axis (cm²).
‡ Includes only cases other than tumor cases (Cases 3 and 7) for which both preoperative and final data are available.
§ Includes only tumor cases (Cases 2, 6, and 8) for which both preoperative and final data are available.
¶ SMAS: superficial musculoaponeurotic system
** Each stage in a cycle with different amounts of saline inflation was maintained for 5 min, followed by deflation for 3 min.

**Table 2. Postoperative course in each case**

| Case | Postoperative days until discharge | Postoperative days until stitch removal | Postoperative complications within a month/treatment | Postoperative complications after a month/treatment | Follow-up period |
|---|---|---|---|---|---|
| 1 | 1 | 14 | None | Erythema (2mo)/healed spontaneously | 3 months (defaulting follow-up) |
| 2 | 2 | 13 | None | Small ulcer formation (2mo)/ointment | 9 months |
| 3 | 10 | 9 | None | None | 5.5 months |
| 4 | 9 | 8 | Folliculitis/ointment | None | 4.5 months |
| 5 | 13 | 9 | None | None | 3 months (still under observation) |
| 6 | 1 | 10 | Fever/alleviated spontaneously | N/A | 2 months (still under observation) |
| 7 | 16 | 14 | N/A | N/A | 2 months (still under observation) |
| 8 | 1 | 14 | Nausea/alleviated spontaneously | N/A | 1 month (still under observation) |

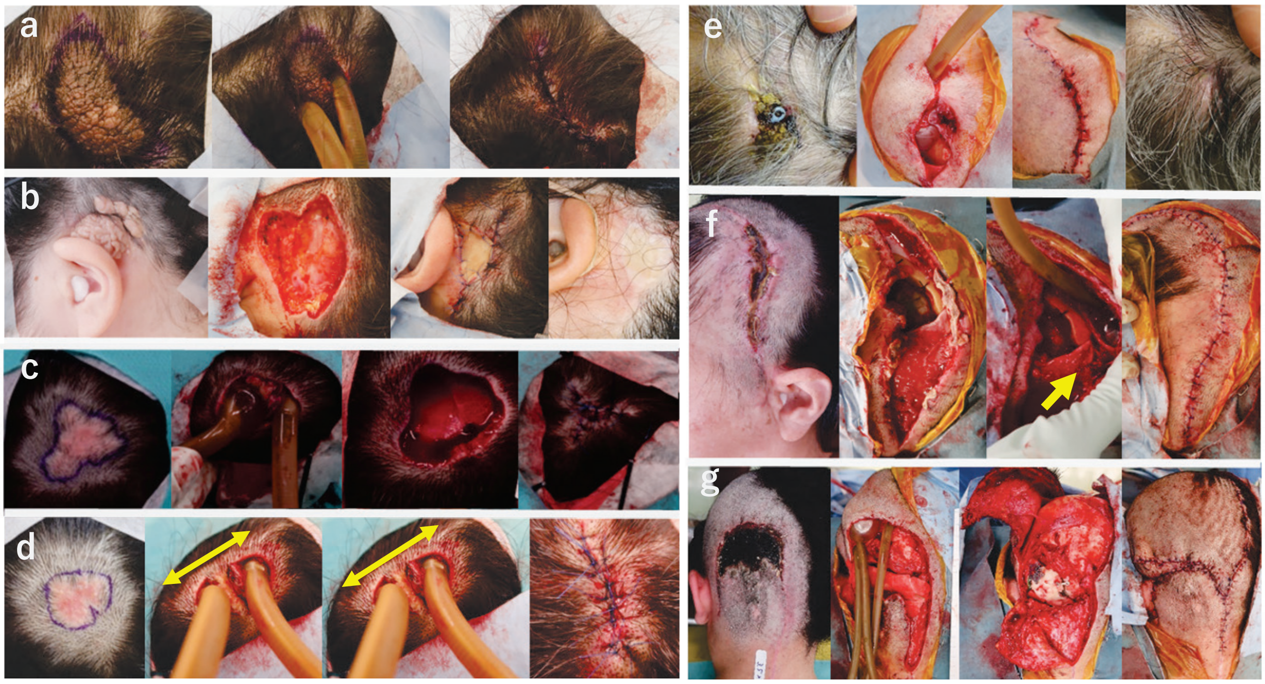


**Figure 2. Photographs of each case:** a, c, d (Case 1, 6, and 8); small incisions are made along the planned incision line, and a catheter is placed before tumor resection. The photographs in the center show the scalp before and after expansion (d; double arrows). b (Case 2); Scalp expansion of hear-bearing skin followed by a skin graft on the glabrous area. The rightmost photograph shows the result 9 months postoperatively. e (Case 3); defect size enlarged due to extended incision for plate removal. The rightmost photograph shows the results 5.5 months postoperatively. f (Case 5); subgaleal catheter insertion (arrow). g (Case 7); three catheters used for the expansion, followed by a local flap procedure. Note: Figures from Case 4 are not included.

the galea, far from the lesion. Although the skin was firm in Case 4, successful closure was achieved, and no complications other than partial folliculitis were observed.

***Wound dehiscence (Case5)***

A 50-year-old female with diabetes mellitus developed wound dehiscence after craniotomy (Figure 2 f). Debridement and expansion at the occipital subgalel plane, with abundant perfusion, were performed under the control of diabetes mellitus, with no complications observed.

***Skin Necrosis (Case7)***

A 22-year-old female presented with scalp necrosis with a maximal preoperative length of 6.0 cm accompanied by cerebrospinal fluid leakage after benign brain tumor removal（Figure 2 g）. Because the defect length was longer than the ideal indication for intraoperative expansion, a rotation flap on the right temporal area and an advancement flap on the left postauricular and occipital areas were created after sufficient scalp expansion. Successful closure was achieved.

## 【Discussion】

The force required for wound closure decreases by 40.1% after skin expansion[8]. Skin expansion aims to reduce wound tension and prevent wound dehiscence, scarring, and alopecia, even in wounds that can be closed primarily by simple undermining. The conventional expansion method provides a maximum extra skin area increase of 137% and a length increase of 52%[9]. However, it requires lengthy treatment with multiple operations, and often results in cosmetic deformities due to the buried expanders during serial expansion, which can significantly disturb the social life of the patient[1,3]. The higher infection rate is another problem with the conventional method, as more infections occur at a younger age. In pediatric patients, 20% experience infections, a rate four times higher than in adults[10, 11]. In contrast, intraoperative expansion can be performed within minutes during a single operation, without the need for postoperative serial expansion, though the amount of extra skin achieved is less, with a 31% increase in area and a 15% increase in length[9]. Collectively, intraoperative expansion can be an ideal treatment for candidates with defects of less than 4.0 to 4.5 cm in length.

As the size of the defect generally expands after tumor resection by about 20% in area[12], preoperative estimation of the future defect size with attention to this tendency is important. The higher error rate shown in our data can be explained by the unity of the defect location at the scalp compared to a variety of anatomical sites in the previous report and the approximation of different shapes as either elliptical or circular. Not only in tumor cases but also in plate exposure or skin necrosis manifested an areal increase in the defect after the procedure, possibly due to expanded incision, acquired wound tension reduction by scar removal, or the necessity of wider debridement. Conventional expansion methods or local flaps are typically recommended for defects exceeding 4.0 to 4.5 cm in length. However, the successful closure of an 8.0 cm defect in our Case 7, achieved through intraoperative scalp expansion followed by local flap application, suggests that combining other treatments with intraoperative scalp expansion can effectively close larger defects than those traditionally considered ideal.

Another issue was the layer in which the balloons were placed. Placement superficial to the galea should be avoided as balloons tend to press the follicles, leading to alopecia[3]. The subgaleal or subperiosteal positions were the most common. In one report, subperiosteal expansion was recommended, as subgaleal dissection predisposes to more bleeding[5]; however, in our experience, a significant amount of bleeding was not observed. Rather, as the galea is the strength layer of the scalp, its dissection allows maximal extension, and preserving an intact periosteum with rich blood flow is of merit in accepting skin grafts[2]. Therefore, we preferred subgaleal insertion unless the layer could not be identified. In contrast, the sub-SMAS provides abundant blood flow and can prevent pressure on the facial nerves around the ear[13].

The repetition of inflation and deflation is an ideal method for expansion, with three to four cycles known to be optimal for maximal extension[14, 15]. The skin starts to extend several minutes after inflation and blood flow recovers within approximately a minute after deflation[1]; thus, deflation is indispensable to prevent ischemia in the skin. We achieved favorable wound closure with fewer cycles of expansion than recommended for small defects. However, for larger defects, four cycles using incremental saline in stages were required.

Mechanisms underlying skin extension during intraoperative expansion have long been discussed. Contrary to the conventional method of neovascularization and capsule formation, in which abundant perfusion is established with true proliferation of cells in the skin[1,8,15], the extension mechanism in intraoperative expansion has been reported as the realignment of collagen fibers in a parallel fashion and flattening by dehydration without true cell proliferation[14]. Another hypothesis is that the skin itself does not extend, but achieves mobility by releasing the adhesion by undermining[16]. In this theory, stretchback occurs in approximately 50% of cases within 12 weeks postoperatively, resulting in alopecia[17]. However, according to a domestic study, alopecia after intraoperative expansion is reported to occur in only 13.9% of cases[6], and some researchers have concluded that the extended skin does not return to its pre-expansion state[18, 19]. Collectively, as our patients manifested no postoperative alopecia, we assume that the skin itself extends to some extent, although a firm approximation of the galea by suturing may also contribute to preventing alopecia. Furthermore, a high skin-stretching ability in the pediatric population has been reported[10], as evidenced in our Cases 6 and 8.

Contraindications include a history of radiation therapy as the skin loses elasticity[4, 6]. The fact that our case, despite significant scarring and adhesion in the skin, was able to extend suggests that the firmness of the skin does not necessarily pose an obstacle to expansion, but rather a history behind the firmness. As was successful in our case, no previous reports have regarded diabetes mellitus as a risk factor for this method. The needlessness of foreign material placement for a long period may contribute to low infection rates in both diabetic patients and the pediatric population.

## 【Limitation】

The limitations of our study include a short follow-up period; thus, a longer observation period is needed.

## 【Conclusion】

Our cases suggest that intraoperative scalp expansion provides ideal defect closure in one-stage operations, even in children or patients with diabetes. Moreover, this method can achieve optimal closure for larger defects than typically recommended when combined with other treatments.

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