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Stepwise Standardization of the Subperiosteal Pocket Technique in Cochlear Implantation: Effects on Surgical Efficiency and Consistency

Koklear İmplantasyonda Subperiostal Cep Tekniğinin Aşamalı Standardizasyonu: Cerrahi Verimlilik ve Tutarlılık Üzerine Etkileri

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ABSTRACT

Objective: The subperiosteal pocket technique (SPT) is widely used in cochlear implantation (CI) for its ability to reduce operative time and minimize complications. This study revisits the technique, focusing on surgical efficiency, stepwise analysis, and implications for training.

Methods: A retrospective analysis of 160 pediatric CI cases was conducted. The total surgery time and durations of eight defined steps were documented, and practical insights were integrated to optimize outcomes.

Results: The cumulative surgical step durations averaged 37.2 ± 6.2 minutes. The most time-intensive steps included suturing and skin closure (13.4 ± 3 minutes) and posterior tympanotomy (7.1 ± 2.7 minutes). These steps were critically analyzed for efficiency and educational value.

Conclusion: The SPT is comparable to conventional methods in safety and effectiveness , with the added benefits of reduced operative time and enhanced training potential. This study provides detailed guidance to improve surgical workflow and education in CI.

Keywords: Subperiosteal pocket, cochlear implantation, surgical training, operative efficiency, pediatric hearing loss

ÖZ

Amaç: Subperiostal cep tekniği (SPT), operasyon süresini kısaltma ve komplikasyonları azaltma potansiyeli nedeniyle koklear implantasyon (Kİ) cerrahisinde yaygın olarak kullanılmaktadır. Bu çalışma, tekniği yeniden ele alarak cerrahi verimlilik, basamaklı analiz ve eğitim açısından çıkarımlar üzerine odaklanmaktadır.

Yöntemler: Toplam 160 pediatrik Kİ olgusunun retrospektif analizi yapıldı. Toplam cerrahi süre ve tanımlanan sekiz cerrahi basamağın süreleri kaydedildi ve sonuçları optimize etmeye yönelik pratik çıkarımlar çalışmaya entegre edildi.

Bulgular: Cerrahi basamakların kümülatif süre ortalaması 37,2 ± 6,2 dakika olarak bulundu. En fazla zaman alan basamaklar sütür ve cilt kapatılması (13,4 ± 3 dakika) ile posterior timpanotomi (7,1 ± 2,7 dakika) idi. Bu basamaklar, verimlilik ve eğitsel değer açısından ayrıntılı olarak analiz edildi.

Sonuç: SPT, güvenlik ve etkinlik açısından konvansiyonel yöntemlerle karşılaştırılabilir olup, daha kısa operasyon süresi ve artmış eğitim potansiyeli gibi ek avantajlar sunmaktadır. Bu çalışma, Kİ cerrahisinde cerrahi iş akışını ve eğitimi geliştirmeye yönelik ayrıntılı rehberlik sağlamaktadır.

Anahtar Sözcükler: Subperiostal cep, koklear implantasyon, cerrahi eğitim, operatif verimlilik, pediatrik işitme kaybı

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INTRODUCTION

Cochlear implants (CIs) are sophisticated electronic devices surgically implanted to restore hearing in individuals with profound or severe hearing loss, for whom conventional sound amplification devices have proven ineffective.

Precision in surgical expertise is essential because of the potential for injury to critical structures, such as the facial nerve, chorda tympani, vestibular system, and cochlear structures, during CI. To ensure sufficient and minimally traumatic electrode insertion while preserving potential residual hearing, high-quality training and deliberate practice are indispensable (1,2).

The traditional gold-standard method for CI fixation involved drilling a bony recess and securing the device with sutures. Although effective, this approach is associated with longer operative time, increased risk of dural tears and cerebrospinal fluid leakage, and greater technical variability (3,4). These challenges have led to the development of alternative techniques such as the subperiosteal pocket method. Recent studies have compared fixation and non-fixation approaches, reporting no significant differences in implant stability (3,4). Furthermore, an international survey demonstrated variability in fixation preferences among CI surgeons (5), and prospective trials, such as the Cochlear Implant Fixation Techniques (COMFIT) study, are ongoing to further investigate these methods (6). In this study, we describe the application of the subperiosteal pocket technique (SPT) without fixation, focusing on a step-by-step description of the surgical timing and technical aspects of the workflow.

The SPT was initially described by Balkany et al. (7) as the temporal pocket technique. This technique has been validated by numerous comparative studies in subsequent years (8-10). It provides advantages in CI because it is easy to perform, shortens operating time, carries a minimal risk of postoperative complications, and does not require external part fixation (8-10).

A technical description serves to organize and standardize the conveyance of information and communication among surgical staff regarding procedural details, thereby potentially enhancing surgical safety (11). Widely adopted, efficacious, standardized, and structured approaches play a crucial role in enhancing surgical safety. A notable example is the integration of the surgical safety checklist, which has demonstrated a substantial decrease in postoperative complications and mortality rates (12,13).

At our tertiary institution, the SPT has been routinely performed in CI since 2008 (8). A growing body of literature on SPT addresses indications, alignment, outcomes, and complications (2,9,10,14). This study revisits the SPT in CI, providing a detailed examination of each surgical step while incorporating practical insights ("tips and tricks") derived from a single-center experience. Additionally, it evaluates the efficiency of each stage and its implications for surgical training. This study analyzes data from pediatric CI surgeries to contribute to the standardization of this technique, to offer actionable guidance for surgeons, and to address the growing need for optimized training methods in CI.

MATERIALS AND METHODS

Study Design and Setting

This retrospective study analyzed pediatric patients who underwent CI using the SPT at our institution between March 2017 and August 2023. Procedural timing and surgical steps were recorded and analyzed based on standardized operative protocols. To ensure methodological consistency and minimize variability, only surgeries performed by a single senior surgeon (Y.G.) with more than 10 years' experience in CI were included. The study was approved by the İstanbul University-İstanbul Faculty of Medicine Clinical Research Ethics Committee (approval number: 2024/940, reference number: 2572440, date: 24.05.2024).

Patient Selection

Patients with severe-to-profound hearing loss, including both prelingual and postlingual cases, were included in the study. Patients with temporal bone abnormalities, anatomical variations, or patients whose surgeries were extended due to abnormal surgical progress (such as instrument or device problems or anesthesia-related complications) were excluded.

Surgical Technique and Analysis

A standardized SPT procedure, divided into eight distinct surgical steps (Figures 1 and 2) was followed:

1. Retroauricular incision and Palva flap elevation.
2. Subperiosteal pocket creation.

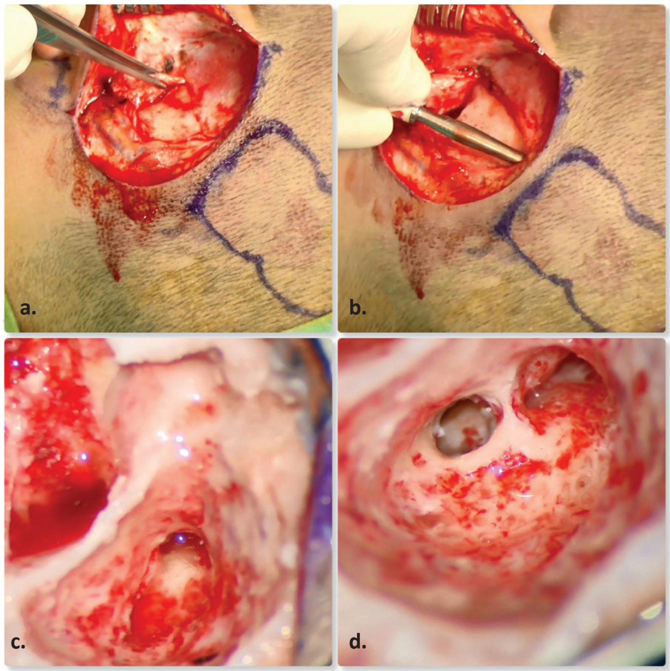

Figure 1. Key steps of the Subperiosteal pocket technique (a), Retroauricular incision with elevation anterior-based tailed Palva flap. (b) Subperiosteal pocket creation. (c) Cortical Mastoidectomy. (d) Posterior tympanotomy.

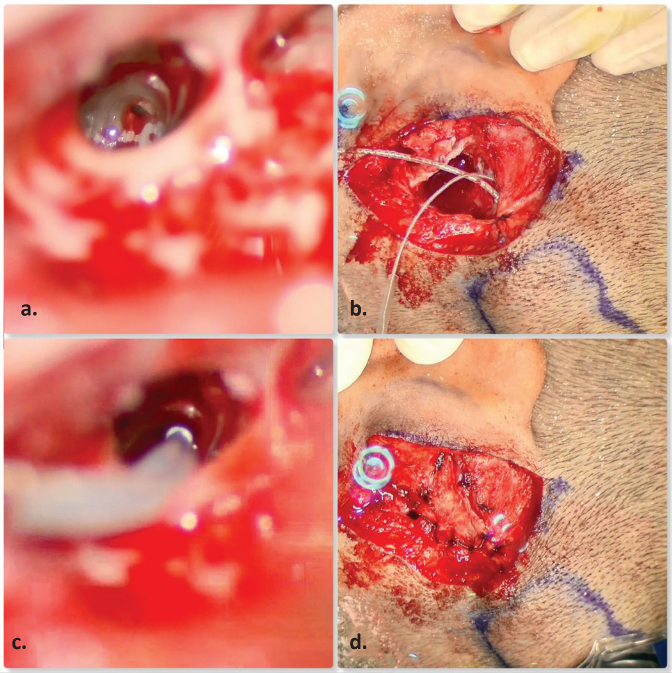

Figure 2. Key steps of the Subperiosteal Pocket Technique, with the subsequent stages continuing in the image. (a) Exposure of round window membrane. (b) Placement of the device in the pocket and suturing tail of Palva flap incision. (c) Electrode array insertion. (d) Suturing Palva flap and skin closure.

3. Cortical mastoidectomy.
4. Posterior tympanotomy.
5. Exposure of the round window (RW) membrane.
6. Placement of the device and suturing of the Palva flap.
7. Electrode array insertion.
8. Suturing of the Palva flap and skin closure.

Surgical technique was analyzed and quantified using surgical video recordings and operative notes. Total surgery time was defined as the duration from skin incision to skin closure. In contrast, cumulative surgical step durations included only the active phases of each of the eight defined steps. For this analysis, a timer was started at the beginning and stopped at the end of each step; short pauses between steps—such as material preparation, instrument handling, and brief workflow interruptions—were not included. Additionally, non–CI-specific intervals such as anesthesia preparation, patient positioning, surgical field preparation, hemostasis, and intraoperative testing were excluded from the cumulative analysis. This exclusion accounts for the difference between cumulative surgical duration and total surgery time.

Technique

Retroauricular Incision with Elevation Anterior-Based Tailed Palva Flap

This technique starts with standard positioning and a C-shaped retroauricular incision, typically placed 8-10 mm posterior to the postauricular skin crease. The incision is extended through the skin and into the subcutaneous tissue. After the posterior auricular muscle is dissected, the auricle is retracted anteriorly over the periosteum. The temporal lines were located through palpation. Following these lines, a 2-cm horizontal periosteal incision was made from the zygomatic root posteriorly using electrocautery. Another periosteal incision, parallel to the initial one, was made at the mastoid tip. These two periosteal incisions were then linked by a posterior vertical incision, creating an anteriorly based musculoperiosteal flap according to Palva's method. Moreover, a tailed Palva flap is created by making a 1–2-cm incision that includes the periosteum, extending from the posterosuperior corner of the flap toward the subperiosteal pocket where the internal receiver will be placed. This modification facilitates atraumatic implant placement and reduces skin tension without compromising the tightness of the subperiosteal pocket (15).

Subperiosteal Pocket Creation

Using the Freer elevator (Karl Storz, Tuttlingen, Germany), a subperiosteal pocket is made according to template of the IRS.

Cortical Mastoidectomy

In a RW approach, a complete mastoidectomy may not always be necessary, but exposing specific anatomical landmarks is crucial for success. These landmarks include the sigmoid sinus, dural plate, mastoid segment of the facial nerve, retrofacial recess, mastoid tip cell, and the thinned outer bony canal wall up to the origin of the chorda tympani at the facial nerve.

Posterior Tympanotomy

For safe access to the RW during CI surgery, the facial recess should be sufficiently widened, particularly inferiorly. The posterior tympanotomy should ideally begin at the origin of the chorda tympani on the facial nerve. It should be widened as much as possible along the chorda and the facial nerve while avoiding exposing the facial nerve sheath to prevent nerve damage and unnecessary bleeding. Opening the inferior facial recess is vital, as it aids in identifying the round window niche (RWN). The Incudal buttress should be protected to help prevent damage to the ossicles during drilling. Preservation of the buttress is necessary, particularly when significant residual hearing is present. In cases of incomplete exposure of the recess, anterior repositioning of the chorda tympani may resolve the issue. If the RW is not visible at this stage, the patient's position may be adjusted to facilitate better visualization, and the posteromedial bone overlying the facial canal may be drilled to expose the medial space of the posterior tympanum. Furthermore, if the visual field is obstructed by the funnel-shaped wall of the external auditory canal (EAC), lowering the EAC's outer margin can help provide a clearer visual field during the procedure.

Exposure of Round Window Membrane

When the RWN was identified after posterior tympanotomy, the anterior and posterosuperior bony overhangs of the RW were carefully removed using a low-speed drill or micro-curette until the annulus of the RW membrane became visible. The pseudomembrane covering the RW membrane was then delicately excised. Additionally, bone adjacent to the anterior-inferior RW annulus might be removed by 1 to 2 mm to facilitate the surgical approach. These meticulous procedures were essential for optimizing the success and safety of RW CI.

Placement of the Device in the Pocket and Suturing Tail of Palva Flap Incision

The inner part of the implant was placed into the previously prepared pocket. The tail flap incision was then closed with absorbable sutures.

Electrode Array Insertion

A sharp, right-angled pick was used to make a vertical incision over the RW membrane, leaving the annulus intact to minimize perilymph leakage. To successfully preserve hearing, the electrode is placed in the anterior-inferior direction and slowly advanced in the posterior-superior direction. The crista semilunaris defines the space available for electrode insertion, primarily within the medial part of the scala tympani.

Suturing the Palva Flap and Skin Closure

Closure of the Palva flap incision and subcutaneous tissue was performed using separate absorbable sutures. For skin closure, intracutaneous absorbable sutures were used.

Statistical Analysis

Operative times were presented as mean ± standard deviation (SD). Differences in the duration of each surgical step were analyzed using one-way analysis of variance (ANOVA). Comparisons between the first and last quartiles of surgeries were performed using paired t-tests to evaluate procedural standardization. Statistical significance was set at $p < 0.05$. Furthermore, variability within steps was assessed using the coefficient of variation (CV).

RESULTS

A total of 160 pediatric patients underwent CI using the SPT. The mean age was 17.4 ± 7.3 months (range: 12–144 months [1–12 years]). Among the patients, 128 (80%) had prelingual hearing loss, while 32 (20%) had postlingual hearing loss. Right ear surgeries accounted for 96 cases (60%), and left ear surgeries for 64 cases (40%).

Operative Time Analysis

The average surgery time as interval skin incision to skin closure 58 ± 3.6 and the average cumulative surgical step durations was 37.2 ± 6.2 minutes. The mean duration, SD, and CV for each surgical step are summarized in Table 1.

Statistical Analysis Results

Stepwise Comparisons: Suturing of the Palva flap and skin closure took significantly longer than all other steps ($p < 0.01$, ANOVA).

- **Variability Across Surgical Steps:** The CV analysis showed that certain steps were performed more consistently than others. Retroauricular incision and Palva flap elevation (CV = 0.14), cortical mastoidectomy (CV = 0.17), device placement with flap suturing (CV = 0.21), and final skin closure (CV = 0.22) demonstrated the lowest variability, indicating a relatively high degree of standardization.
- **Learning Curve and Procedural Consistency:** A comparison of the first and last quartiles of surgeries revealed no significant difference in total operative time ($p = 0.6$), suggesting stable surgical performance over time. Furthermore, variability patterns across steps did not differ significantly between early and late cases ($p = 0.8$, t-test), supporting the overall standardization of the technique within this surgical series.

Complications

No intraoperative complications, including facial nerve injury, bleeding requiring additional intervention, or difficulties during electrode insertion, were observed. Similarly, no postoperative complications were noted; in particular, no device migration occurred, and all postoperative evaluations confirmed correct and stable positioning of the implants.

DISCUSSION

This study revisited the SPT in CI, providing a step-by-step analysis of surgical efficiency and its implications for training. By evaluating 160 pediatric cases, we identified critical areas for optimization and standardization.

The average cumulative surgical step duration was 37.2 ± 6.2 minutes, which aligns with the technique's reputation for reducing operative time. Among the eight procedural steps, suturing the Palva flap and closing the skin (13.4 ± 3 minutes) and posterior tympanotomy (7.1 ± 2.7 minutes) were the most time-intensive, accounting for a significant portion of the operative time. In contrast, steps such as subperiosteal pocket creation and electrode array insertion exhibited minimal variability and consistently shorter durations. This suggests that these steps are well standardized and less influenced

Table 1. Mean duration, standard deviation, and coefficient of variation for each of the eight surgical steps.

Surgical step	Mean duration (min)	SD (min)	Coefficient of variation
Retroauricular incision and Palva flap elevation	4.4	0.60	0.14
Subperiosteal pocket creation	1.2	0.37	0.31
Cortical mastoidectomy	5.2	0.90	0.17
Posterior tympanotomy	7.1	2.70	0.38
Round window membrane exposure	1.3	0.75	0.58
Device placement and Palva flap suturing	3.4	0.70	0.21
Electrode array insertion	1.2	0.50	0.42
Suturing of the Palva flap and skin closure	13.4	3.00	0.22

SD: Standard deviation, min: Minimum.

by surgeons' experience. In contrast, more complex steps such as posterior tympanotomy and suturing are affected by factors such as anatomical variations, surgeon experience, and the equipment used, which makes them more variable and challenging to standardize. Identifying these differences provides an opportunity to refine the more variable and time-consuming steps, thereby enhancing efficiency and reducing overall surgical duration, particularly in high-volume centers.

Numerous studies have demonstrated the reliability of SPT, showing an absence of device migration and, in some instances, spontaneous bone bed formation (15-18). Conventional methods for securing CIs typically include the creation of a bony bed and a channel within the calvarium, sometimes accompanied by tie-down sutures. However, the process of drilling through potentially thin calvarial bone carries the risk of rare but severe complications, such as epidural hematoma, cerebral infarction, and cerebrospinal fistulae (19-22). The shift towards the SPT can be attributed to its potential to mitigate these complications and reduce operation time. This trend underscores the growing recognition of the technique's advantages in enhancing patient safety and optimizing surgical efficiency (8-10,14,23).

A cross-sectional survey of the American Neurotology Society elucidated the collective preferences for internal device fixation in CI. Among the respondents, 65% expressed a predilection for a variation of the tight SPT, highlighting its prevalence in contemporary practice. The survey further revealed that 19% favored a bony bed and trough with tie-downs, 10% preferred a bony bed and trough without tie-downs, and 5% opted for a screw fixation system. Within the subset of respondents endorsing the SPT, 62% incorporated a bony trough, while 38% performed the SPT alone, underscoring the diversity of approaches within this specialized field (23).

Recent studies have highlighted the ongoing debate regarding COMFITs and their surgical implications (3-5,24). While multiple fixation methods, including bony bed preparation and tight subperiosteal pockets, have been proposed, systematic reviews have shown no significant differences in implant stability between these approaches (3,24,25). In line with these findings, the present study focused not on comparing fixation methods but rather on providing a detailed, step-by-step technical description of the SPT without fixation, and on analyzing surgical timing for each stage. Our results support the conclusion that the technique can be standardized with minimal variability across key surgical steps, thereby contributing to procedural reproducibility and educational frameworks. Moreover, recent international surveys emphasize the variability in surgeons' practices regarding fixation (5), reinforcing the need for clearly structured protocols rather than reliance on fixation type alone.

The simplicity and efficiency of the SPT make it highly suitable for surgical education and for reproducible clinical practice. In our series, total operative times did not differ significantly between the early and late surgical quartiles ($p = 0.6$), indicating consistent performance over time and suggesting that the procedure can be mastered without a prolonged learning curve. Variability analysis further supported this observation: steps such as retroauricular incision, cortical mastoidectomy, device placement, and final skin closure showed the lowest coefficients of variation, indicating a high degree of procedural standardization. In contrast, greater variability in steps such as posterior tympanotomy, RW exposure, subperiosteal pocket creation, and electrode insertion was observed, likely reflecting differences in anatomy, surgical complexity, and case-specific technical adjustments. This structured and stepwise breakdown of the procedure facilitates targeted learning by helping trainees focus on the more variable and technically demanding steps, while reliably executing the more standardized components. Historically, surgical skills have been transmitted through the master-apprentice model in which the apprentice begins by observing the master and gradually assumes more responsibility until capable of performing the procedure independently (26-28). However, changes in working-hour regulations and the increasing focus on operational efficiency have reduced instructional time, posing challenges for surgical education (29). In this context, a step-by-step framework like the one described in this study offers a standardized breakdown of procedures, enhancing education, communication, and evaluation for trainees. It ensures that critical skills are effectively imparted despite time constraints (28).

Our findings also highlight the relationship between the surgeon's experience and operative time. The SPT demonstrated a learning curve comparable to previous studies of stapedectomy, in which surgeons required 60–100 cases to achieve full proficiency (30-32). Adopting a standardized technique and surpassing this threshold resulted in significant reductions in operative time, which eventually plateaued as surgeons reached a high level of competence. This underscores the value of procedural standardization in optimizing both surgical efficiency and training outcomes.

The estimated cost for operating room time, encompassing both anesthesia and facility fees, is $42 per minute (33). Therefore, surgical duration is positively correlated with costs. In a different study using data from 2006–2007, the facility fee at another institution was $1,581 for the first 30 minutes of surgery and $1,265 for each subsequent half-hour. The facility fee alone has been reported as $6,641 for the standard unilateral CI procedure, which has a duration of 144 minutes. When Combined with the implant's list price of $28,900, the total bill reached $35,541. Additional fees, such as those for the recovery room, anesthesia, laboratory, pharmacy, surgeon, anesthesiologist, clinic, and other related costs, are not included in this calculation (34). We believe that our surgical description contributes to reducing surgical duration and, consequently, costs.

Study Limitations

One limitation of our study is its retrospective design, which may introduce biases in data collection and interpretation. Furthermore, our analysis focused exclusively on pediatric cases, limiting the generalizability of the findings to adult populations. At the time of the surgical interventions included in this study, the standard clinical practice at our institution typically resulted in implantation at a mean age of 17.4 months, which was influenced by national guidelines, referral patterns, and parental factors. We recognize the growing emphasis on implantation before 12 months of age in contemporary clinical practice. Moreover, this study did not assess functional or patient-reported outcome measures (PROMs), which are increasingly recognized as important indicators of surgical success and patient satisfaction (35). Prospective studies could expand on these findings by incorporating long-term outcomes such as device stability, patient satisfaction, PROMs, and cost-effectiveness to further validate the advantages of the SPT.

CONCLUSION

This study concludes that the SPT is an efficient approach to CI, offering reduced operative time and a structured framework suitable for surgical training. By identifying time-intensive steps and analyzing procedural efficiency, this technique can be further optimized to enhance its clinical and educational utility. Future studies with diverse populations and long-term follow-up are recommended to expand on these findings.

Ethics

Ethics Committee Approval: The study was approved by the İstanbul Faculty of Medicine Clinical Research Ethics Committee (approval number: 2024/940, reference number: 2572440, date: 24.05.2024).

Informed Consent: Informed consent was not required due to the retrospective design of the study and the use of anonymized surgical records.

Footnotes

Authorship Contributions

Surgical and Medical Practices: S.S., M.Ç., B.P., D.A., K.S.O., Y.G., Concept: S.S., M.Ç., B.P., D.A., K.S.O., Y.G., Design: S.S., M.Ç., B.P., D.A., Data Collection or Processing: S.S., M.Ç., B.P., D.A., K.S.O., Y.G., Analysis or Interpretation: S.S., M.Ç., B.P., K.S.O., Y.G., Literature Search: S.S., M.Ç., B.P., K.S.O., Writing: S.S., M.Ç.

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