scientific reports

Check for updates

OPEN

Retrospective analysis of clinical outcomes and early complications of conventional circumcision techniques and thermocautery-assisted circumcision

Bedreddin Kalyenci[1]✉, Can Benlioglu[1], Mahmut Taha Ölçücü[2], Kerem Teke[3], Sait Sever[4], Ali Çift[1] & Mehmet Özgür Yücel[1]

This study compared various circumcision techniques, specifically the dorsal slit (DS), sleeve resection (SR), and forceps-guided (FG) techniques, which fall under the category of conventional circumcision techniques, with the thermocautery-assisted circumcision (TAC) technique. The aim was to investigate the safety and efficacy of these circumcision methods by focusing on clinical outcomes and early complications, categorizing the associated complications using the Clavien-Dindo classification system (CDCS). A total of 7041 circumcised patients were retrospectively analyzed and grouped according to the applied techniques: DS, SR, FG, and TAC. Factors such as age, duration of the procedure, bleeding, edema, infection, recovery time, and local anesthetic technique parameters were compared. Complications were classified according to the modified CDCS. The duration of the procedure was 4.7 min (range 4.5–5.2), and bleeding (hematoma) was significantly lower in the TAC group with seven cases (0.3%) ($p < 0.001$). The recovery time of 5 days (range 5–7 days) and the incidence of edema were longer in TAC compared to other techniques ($p < 0.001$). Additionally, the recovery time in the SR group was shorter than that of the FG and DS groups ($p < 0.001$). After adjusting for confounding factors such as age, duration of the procedure, and local anesthetic techniques, the likelihood of perioperative bleeding was observed to statistically significantly increase in the FG (odds ratio [OR] = 61.663, 95% confidence interval [CI] 42.764–88.913, $p < 0.001$), DS (OR = 59.249, 95% CI 39.382–89.141, $p < 0.001$), and SR (OR = 161.952, 95% CI 96.100–272.930, $p < 0.001$), in that order, compared to the TAC group. Furthermore, compared to the TAC group, the likelihood of severe edema statistically significantly decreased in the FG (OR = 0.010, 95% CI 0.004–0.027, $p < 0.001$), DS (OR = 0.040, 95% CI 0.017–0.092, $p < 0.001$), and SR (OR = 0.043, 95% CI 0.015–0.124, $p < 0.001$) groups, in that order. There was no significant difference between the surgical techniques according to the CDCS evaluation. TAC demonstrated advantages over the remaining techniques in terms of less bleeding and shorter duration of the procedure. However, it also presented with disadvantages such as postoperative edema and longer recovery time.

Keywords Circumcision, Clavien-Dindo classification system, Bleeding, Edema, Thermocautery

Male circumcision, a widely practiced surgical procedure worldwide, involves the removal of part of the penile foreskin for cultural, religious, and medical purposes[1]. Circumcision offers various benefits, such as a reduction in the incidence of urinary tract infections, penile cancer, and sexually transmitted diseases[2–4].

Many different circumcision techniques have been developed. Categorically, circumcision techniques can be divided into classical surgical methods and device-assisted approaches. Conventional circumcision techniques (CCTs), which are performed with standard surgical equipment, include dorsal slit (DS), sleeve resection (SR), and forceps-guided (FG) techniques, as well as special clamp-based methods, e.g., Gomco, Mogen, PlastiBell,

[1]Department of Urology, Faculty of Medicine, Adıyaman University, 02040 Adiyaman, Turkey. [2]Department of Urology, Antalya Training and Research Hospital, 07100 Antalya, Turkey. [3] Department of Urology, Faculty of Medicine, Kocaeli University, 41001 Kocaeli, Turkey. [4]Department of Urology, Adıyaman Training and Research Hospital, 02100 Adiyaman, Turkey. ✉email: bedreddin84@windowslive.com

Tara, and Shang ring techniques[5]. Although thermocautery-assisted circumcision (TAC) seems to be a technique similar to CCTs, its popularity has increased in recent years due to the reduced bleeding rates after circumcision with the use of thermal energy instead of a scalpel during the cutting of the foreskin[6].

As with any surgical procedure, circumcision may involve potential complications. Literature reports complication rates ranging from 0.1–35%[7]. In addition to early complications such as bleeding, infection, and edema, late complications may include urethral chordee, inadequate preputial excision, penile adhesions, phimosis, buried penis, urethrocutaneous fistulas, and meatal stenosis[8]. The question of which technique is advantageous in which situation can be addressed through the sharing of surgical experiences and complications encountered. The clinical outcomes and complications of circumcision are likely to be affected by the histopathological differences in penile tissue resulting from the use of a scalpel versus thermocautery[9].

This study compared the clinical outcomes and early complications of DS, SR, and FG, which fall under the category of CCTs, with the TAC technique. The modified Clavien-Dindo classification system (CDCS) was used to standardize the classification of complications. The aim of the study was to provide a comprehensive overview of the advantages and disadvantages of CCTs and the TAC technique by presenting data on clinical outcomes and early complications.

Methods

This retrospective cohort study analyzed the data screened from 7,041 patients circumcised between January 1, 2016, and May 5, 2021, at two different centers. The study was approved by the Scientific Research Permit Commission of the Ağrı Provincial Health Directorate (meeting date: July 8, 2021, decision number: 60). All methods were conducted in accordance with the relevant guidelines and regulations. Informed consent was obtained from all patients and/or their legal guardians. Male patients who underwent circumcision for cultural, religious, or medical reasons, either by family or personal choice, were included in the study. Patients with additional conditions that could affect post-circumcision complications; those with hypospadias, bleeding disorders, allergic reactions to anesthetics, or a history of systemic diseases; and those who had undergone penile surgery, were excluded from the study. The operations were performed by a total of six different surgeons at two different centers. The technique selection of each surgeon was based on their personal experience and practice.

Surgical preparation

In all techniques, the genital area was first cleaned with soap and clean water to remove visible dirt and debris. Subsequently, the skin was disinfected using a 10% povidone-iodine aqueous solution (Poviiodeks, Kimpa, Turkey) applied three times, starting from the glans penis and penile shaft and moving outward. After the third application, the iodine solution was left on the skin for at least 2 min to dry naturally. A single fenestrated drape was used for the penis. The glans and the retractable foreskin were retracted, and any remaining smegma was cleansed using the 10% povidone-iodine solution (Poviiodeks, Kimpa, Turkey).

Local anesthesia

All patients received local anesthesia via a mixture of lidocaine HCl 20 mg/mL (Jetmonal, Adeka, Turkey) and bupivacaine 0.5% (Marcaine, Sanofi, Turkey) in a 1:1 ratio. The dosage was limited to 3 mg/kg for lidocaine and 1.5 mg/kg for bupivacaine. To ensure vascular control, the syringe was aspirated prior to injection to confirm the absence of blood. Depending on the surgeon's experience and preference, penile local anesthesia was administered as either a subcutaneous ring block or a dorsal nerve block[10].

Sedoanalgesia

For patients receiving sedoanalgesia, intravenous administration of a vial containing 4.5 mg/kg ketamine HCl (Ketalar, Pfizer, USA) and an ampoule containing 0.1–0.5 mg/kg midazolam (Sedozolam, Monemfarma, Turkey) was performed. Dosages for sedoanalgesia were adjusted as needed during sedation under the supervision of an anesthesiologist.

Circumcision techniques

In all techniques, the circumcision line was delineated either with a marker or by creating compression marks.

Forceps-guided (FG) technique

The foreskin was grasped using two clamp forceps at the 6:00 and 12:00 positions. The forceps were aligned along the longitudinal axis from 12:00 to 6:00, and the tissue was incised with a scalpel. If a large mucosal cuff remained, additional excision of mucosal tissue was performed using scissors, with forceps applied at the 3:00, 9:00, and 12:00 positions (Fig. 1a).

Dorsal slit (DS) technique

The foreskin was tightly grasped with clamp forceps placed at the 1:00 and 11:00 positions. A dorsal slit line was created by compressing the tissue with a straight clamp forceps positioned at 12:00, between the two clamps at 11:00 and 1:00. Dissection scissors were then used to create a circumferential incision on the mucosal side, starting from the dorsal slit line (Fig. 1b).

Sleeve resection (SR) technique

Two separate incision lines, known as the outer and inner incision lines, were marked. The skin and subcutaneous tissue were excised along these marked lines using a scalpel (Fig. 1c).

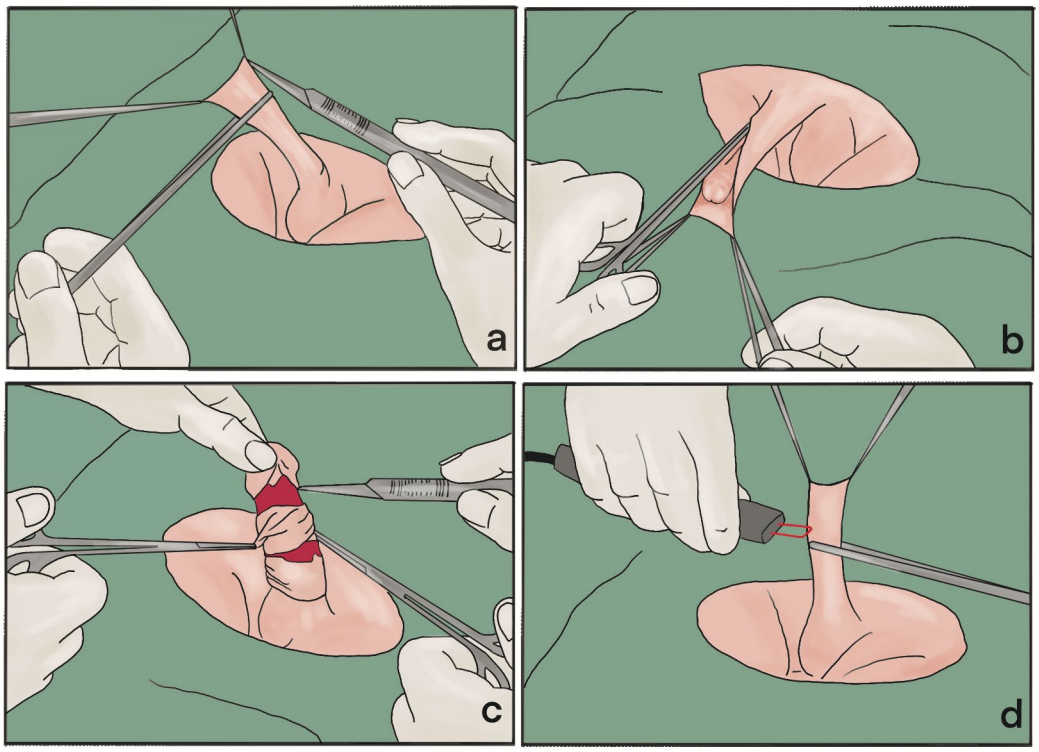

Fig. 1. Illustrations of circumcision techniques: (**a**) Forceps-guided, (**b**) dorsal slit, (**c**) sleeve resection (SR), and (**d**) thermocautery-assisted circumcision.

Thermocautery assisted circumcision (TAC) technique
This technique was similar to the FG method, but, instead of a scalpel, a thermocautery device (Warme Medizinische Beschneidung Gerat, QX-2100, Germany) was used for tissue incision (Fig. 1d).

Suturing and dressing
Synthetic absorbable sutures, typically 4/0 to 3/0, were used for skin closure. Hemostatic dressings and adhesive bandages were applied to prevent bleeding.

Follow-up and discharge
Patients who received sedation were observed for at least 8 h, while those with local anesthesia were monitored for at least 3 h. Patients without postoperative issues such as bleeding or allergic reactions were discharged. For home care, patients under 15 years of age were prescribed ibuprofen oral suspension (20–30 mg/kg; Dolven, Sanofi, France), and those over 15 were recommended 500 mg paracetamol tablets (Parol, Atabay, Turkey) twice daily as an analgesic.

Patients were advised to rest, wear loose-fitting skirts or underwear suitable for circumcision, and bathe only after three days postoperatively. Immediate medical attention was recommended in cases of bleeding, discoloration of the glans penis, pain unresponsive to analgesics, swelling, or discharge from the incision site. Routine follow-ups were typically scheduled for the 10th postoperative day, although some patients were monitored more frequently or advised to visit the clinic only if complications arose. Telemedicine was also utilized for follow-up in certain cases.

The resolution of edema was observed at varying intervals, and the patients were categorized based on duration: mild edema for four to seven days, moderate edema for seven to 10 days, and severe edema for 10 or more days. Treatment for mild or moderate edema cases was relatively straightforward, and no additional concerns were reported by patients or their guardians. Patients with severe edema were advised to continue taking ibuprofen, apply topical hydrocortisone cream, and change their dressings daily.

In evaluating infections, individuals who did not require additional treatment were categorized as non-infected. Infected patients were divided into three groups: mild (redness and color changes), moderate (exudate or minimal necrosis with less than 1 cm^2), and severe infections (continuous discharge or significant necrosis with more than 1 cm^2). A healing wound was defined as the presence of intact skin between sutures, with no exudate or swelling. Recovery time was assessed based on the achievement of complete healing.

All data, including surgical notes, clinic follow-up notes, telemedicine follow-up notes, and patient files, were reviewed. The collected data included age, circumcision technique, type of local anesthesia, bleeding, duration of the procedure, number of sutures, edema, infection, recovery time, and other complications. The duration of the procedure was recorded in minutes from the incision of the foreskin to the last suture. The number of sutures

was recorded from the surgical notes based on each surgeon's technique and the number of sutures used. Both perioperative and postoperative complications were documented and categorized according to the CDCS.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics version 17.0 software (IBM Corporation, Armonk, NY, USA). Whether the distributions of continuous variables were normally or not being determined Kolmogorov-Smirnov test. The assumption of homogeneity of variances was examined Levene test. Categorical data were expressed as numbers (n) and percentage (%) while quantitative data were given as median (25th - 75th) percentiles. The Kruskal Wallis test was applied for the comparisons of the continuous variables which the parametrical test assumptions were not met. When the p-values from Kruskal Wallis test were statistically significant, Dunn-Bonferroni test was used to know which group differ from which others. Pearson's $\chi 2$ test was used in the analysis of categorical data unless otherwise stated. On the other hand, in all 2 x 2 contingency tables to compare categorical variables; the Continuity corrected $\chi 2$ test was used when one or more of the cells had an expected frequency of 5-25, otherwise, the Fisher's exact test was used when one or more of the cells had an expected frequency of 5 or less. The effects of conventional circumcision techniques on main outcome variables (i.e., bleeding type, severity of edema, and infection) according to TAC after adjustment for other confounding factors (i.e., age, local anesthetic techniques, and duration of procedure) were investigated by multinomial logistic regression analysis. Odds ratios (OR), 95% confidence intervals (CI), and Wald statistics for each independent variable were also calculated. A p value less than 0.05 was considered statistically significant.

Results

Demographic and clinical characteristics

The mean age was significantly lower in the TAC group compared to the FG, DS, and SR groups ($p < 0.001$) (Table 1). The TAC group exhibited a significantly higher incidence of dorsal nerve block administration compared to the FG, DS, and SR groups ($p < 0.001$). In addition, the rate of subcutaneous ring block administration in the SR group was statistically significantly higher than in the FG and DS groups ($p = 0.009$ and $p = 0.049$, respectively) (Table 2).

Duration of procedure

The mean duration of the procedure was the shortest in the TAC group at 4.7 min (range: 4.5–5.2 min), while the SR group had the longest duration at 25 min (range: 24–28 min) ($p < 0.001$) (Fig. 2).

Number of sutures

The TAC group required the fewest sutures, with a mean of 5 (range: 4–7), which was significantly lower compared to the FG, DS, and SR groups ($p < 0.001$).

Recovery time

The recovery time was significantly longer than in the TAC group, with a median of 5 days (range: 5–7 days) compared to the remaining groups ($p < 0.001$). Furthermore, the recovery time in the SR group was statistically significantly shorter compared to the FG and DS groups ($p < 0.001$).

Bleeding

The incidence of bleeding (both intraoperative and postoperative) was significantly lower in the TAC group compared to the FG, DS, and SR groups ($p < 0.001$) (Table 3). In addition, the postoperative bleeding rate in the SR group was statistically significantly higher than in the FG group ($p = 0.045$). The incidence of hematoma in the TAC group was also statistically significantly lower than in the FG and SR groups ($p = 0.036$ and $p = 0.003$). No statistically significant difference was observed in other pairwise comparisons between the groups or in hematoma evacuation requiring surgery ($p > 0.05$) (Fig. 3). After adjusting for age, duration of the procedure, and local anesthesia techniques, the likelihood of perioperative bleeding compared to the TAC group significantly increased in the FG (odds ratio [OR] = 61.663, 95% confidence interval [CI]: 42.764–88.913, $p < 0.001$), DS (OR = 59.249, 95% CI 39.382–89.141, $p < 0.001$), and SR (OR = 161.952, 95% CI 96.100–272.930, $p < 0.001$) groups, in that order. Similarly, postoperative bleeding risk remained statistically significantly higher in these groups (Table 4).

Edema

The overall incidence of edema was significantly higher in the TAC group compared to the remaining groups ($p < 0.001$) (Fig. 4). After adjusting for age, surgery duration, and local anesthesia techniques, the likelihood of severe edema compared to the TAC group significantly decreased in the FG (OR = 0.010, 95% CI: 0.004–0.027, $p < 0.001$), DS (OR = 0.040, 95% CI: 0.017–0.092, $p < 0.001$), and SR (OR = 0.043, 95% CI: 0.015–0.124, $p < 0.001$) groups, in that order (Table 5).

Infection

The FG group showed a higher overall infection incidence and rate of mild infections compared to the TAC group ($p = 0.046$ and $p < 0.001$, respectively) (Table 3). After adjusting for age, surgery duration, and local anesthesia techniques, no statistically significant differences were identified between the TAC group and the FG, DS, or SR groups in terms of moderate or severe infections ($p > 0.05$) (Table 6).

	n = 7,041
Age (years)*	9 (6–11)
Circumcision technique**	
Forceps-guided	3,209 (45.6)
Dorsal slit	611 (8.7)
Sleeve resection	708 (10.0)
Thermocautery-assisted circumcision	2,513 (35.7)
Type of anesthesia**	
Local anesthesia	5,530 (78.5)
Sedation and local anesthesia	1,511 (21.5)
Local anesthetic techniques**	
Subcutaneous ring block	3,705 (52.6)
Dorsal nerve block	3,336 (47.4)
Bleeding**	
None	5,739 (81.5)
Perioperative	1,006 (14.3)
Postoperative	254 (3.6)
Hematoma	42 (0.6)
Duration of procedure (min)*	15.0 (5.1–19.0)
Number of sutures*	8 (6–8)
Edema**	
None	5,657 (80.3)
Mild	702 (10.0)
Moderate	577 (8.2)
Severe	105 (1.5)
Infection**	
None	6,815 (96.8)
Mild	162 (2.3)
Moderate	46 (0.6)
Severe	18 (0.3)
Recovery time (day)*	5 (4–5)
Complications**	33 (0.5)
Clavien-Dindo score**	
0	5,724 (81.3)
1	1,245 (17.7)
2	43 (0.6)
3a	19 (0.3)
3b	9 (0.1)
4	1 (0.014)

Table 1. Demographic and clinical characteristics of cases. *Data presented as median (25th –75th percentiles) for continuous variables, **Data presented as number (%) of cases for categorical variables.

Complication rates according to CDCS

There were no statistically significant differences among the surgical techniques regarding the overall incidence of complications ($p = 0.593$). Grade 1 complications were managed on an outpatient basis with pressure dressings, oral antibiotics, and analgesics. 2 Grade 2 complications required hospitalization for intravenous treatments (e.g., antibiotic therapy and methylene blue treatment) and follow-up for bleeding with pressure dressings. Grade 3 complications necessitated surgical procedures such as debridement or hematoma drainage (Grade 3a under local anesthesia and Grade 3b under general anesthesia). On the other hand, after adjusting for age, duration of the procedure, and local anesthetic techniques, although the likelihood of hematoma increased in the FG, DS, and SR groups compared to the TAC group, the results were not statistically significant in relation to the surgical evacuation of the hematoma ($p > 0.05$). One case of Grade 4a complications involved organ loss, specifically penile amputation.

Compared to the FG, DS, and TAC groups, the rate of patients with a CDCS score of 0 was significantly higher in the SR group ($p = 0.024$, $p < 0.001$, and $p < 0.001$, respectively). The rate of patients with a CDCS score of 0 was significantly lower in the DS and TAC groups compared to the FG group ($p < 0.001$). Additionally, the rate of patients with a CDCS score of 1 was significantly lower in the SR group compared to the FG, DS, and TAC groups ($p = 0.041$, $p < 0.001$, and $p < 0.001$, respectively). Furthermore, the rate of patients with a CDCS score of 1 was significantly higher in the DS and TAC groups compared to the FG group ($p < 0.001$). Finally, the

	Forceps-guided ($n=3,209$)	Dorsal slit ($n=611$)	Sleeve resection ($n=708$)	TAC ($n=2,513$)	p-value
Age (years)*	9 (6–12)^{A}	11 (7–15)^{B}	11 (7–15)^{B}	8 (6–10)^{C}	**<0.001**[1]
Type of anesthesia**					0.061[2]
Local anesthesia	2,512 (78.3)	492 (80.5)	532 (75.1)	1,994 (79.3)	
Sedation and local anesthesia	697 (21.7)	119 (19.5)	176 (24.9)	519 (20.7)	
Local anesthetic techniques**					**<0.001**[2]
Subcutaneous ring block	1,828 (57.0)^{A}	348 (57.0)^{A}	441 (62.3)^{B}	1,088 (43.3)^{C}	
The dorsal nerve block	1,381 (43.0)^{A}	263 (43.0)^{A}	267 (37.7)^{B}	1,425 (56.7)^{C}	
Duration of procedure (min)*	17 (15–20)^{A}	18 (15–20)^{A}	25 (24–28)^{B}	4.7 (4.5–5.2)^{C}	**<0.001**[1]
Number of sutures*	8 (8–8)^{A}	8 (8–8)^{A}	8 (8–8)^{A}	5 (4–7)^{B}	**<0.001**[1]
Recovery time (day)*	4 (3–5)^{A}	4 (3–5)^{A}	4 (3–4)^{B}	5 (5–7)^{C}	**<0.001**[1]

Table 2. Comparison of demographic and clinical characteristics among circumcision techniques. TAC: thermocautery-assisted circumcision. *Data presented as median (25th-75th percentiles) for continuous variables, **Data presented as number (%) of cases for categorical variables[1]. Kruskal-Wallis test[2], Pearson's χ^2 test. $^{A-C}$No statistically significant differences between the groups with the same upper-case letters ($p>0.05$). Significant values are in bold.

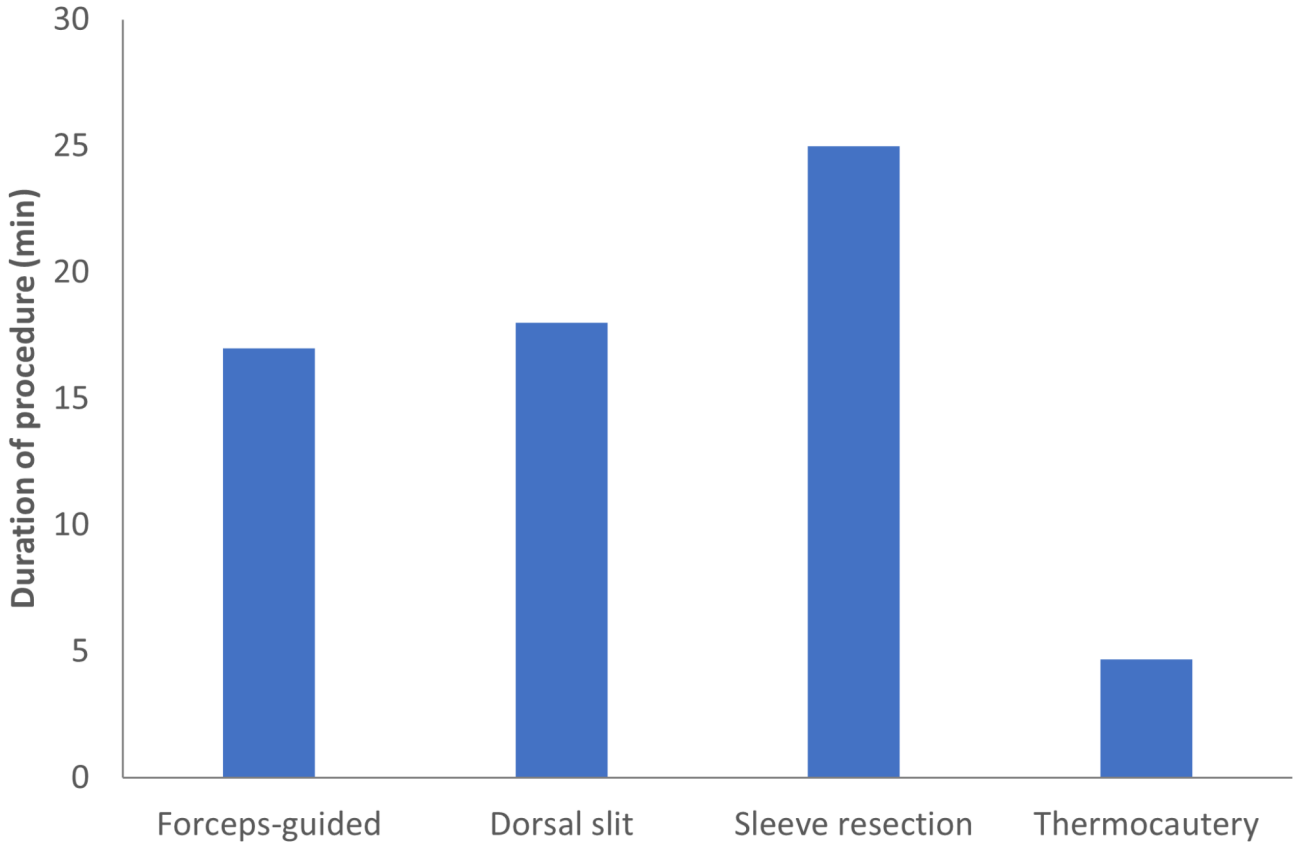

Fig. 2. Duration of procedure in study groups.

rate of patients with a CDCS score of 3b was significantly higher in the DS group compared to the TAC group ($p=0.025$) (Table 7).

Rare complications

Rare complications in procedures such as circumcision, which is often performed for non-medical reasons, should be considered a significant cost. In this case series presenting a large number of cases, each of these rare complications, which we encounter infrequently, requires a unique management approach and has been shared in the literature in the form of case reports. In this article, these rare complications will be briefly discussed, and a general perspective on the complications will be provided.

	Forceps-guided ($n=3,209$)	Dorsal slit ($n=611$)	Sleeve resection ($n=708$)	TAC ($n=2513$)	p-value [1]
Bleeding					< 0.001
None	2319 (72.3)^{A}	493 (80.7)^{B}	489 (69.1)^{A}	2438 (97.0)^{C}	
Perioperative	709 (22.1)^{A}	85 (13.9)^{B}	162 (22.8)^{A}	50 (2.0)^{C}	
Postoperative	158 (4.9)^{A}	30 (4.9)$^{A, B}$	48 (6.8)^{B}	18 (0.7)^{C}	
Hematoma	23 (0.7)^{A}	3 (0.5)$^{A, B}$	9 (1.3)^{A}	7 (0.3)^{B}	
Edema					**< 0.001**
None	3093 (96.4)^{A}	588 (96.3)^{A}	687 (97.0)^{A}	1289 (51.3)^{B}	
Mild	81 (2.5)^{A}	10 (1.6)^{A}	11 (1.6)^{A}	600 (23.9)^{B}	
Moderate	28 (0.9)^{A}	11 (1.8)^{A}	9 (1.3)^{A}	529 (21.0)^{B}	
Severe	7 (0.2)^{A}	2 (0.3)^{A}	1 (0.1)^{A}	95 (3.8)^{B}	
Infection					**0.045**
None	3095 (96.5)^{A}	592 (96.9)$^{A, B}$	681 (96.2)$^{A, B}$	2447 (97.4)^{B}	
Mild	93 (2.9)^{A}	11 (1.8)$^{A, B}$	19 (2.7)$^{A, B}$	39 (1.5)^{B}	
Moderate	14 (0.4)^{A}	6 (1.0)^{A}	6 (0.8)^{A}	20 (0.8)^{B}	
Severe	7 (0.2)^{A}	2 (0.3)^{A}	2 (0.3)^{A}	7 (0.3)^{B}	
Complication					0.593
No	3194 (99.5)	606 (99.2)	705 (99.6)	2503 (99.6)	
Yes	15 (0.5)	5 (0.8)	3 (0.4)	10 (0.4)	

Table 3. Comparison of morbidity among circumcision techniques. TAC: thermocautery-assisted circumcision. Descriptive statistics are presented as number (%) of cases[1]. Pearson's χ^2 test. $^{A–C}$No statistically significant differences between the groups with the same upper-case letters ($p > 0.05$). Significant values are in bold.

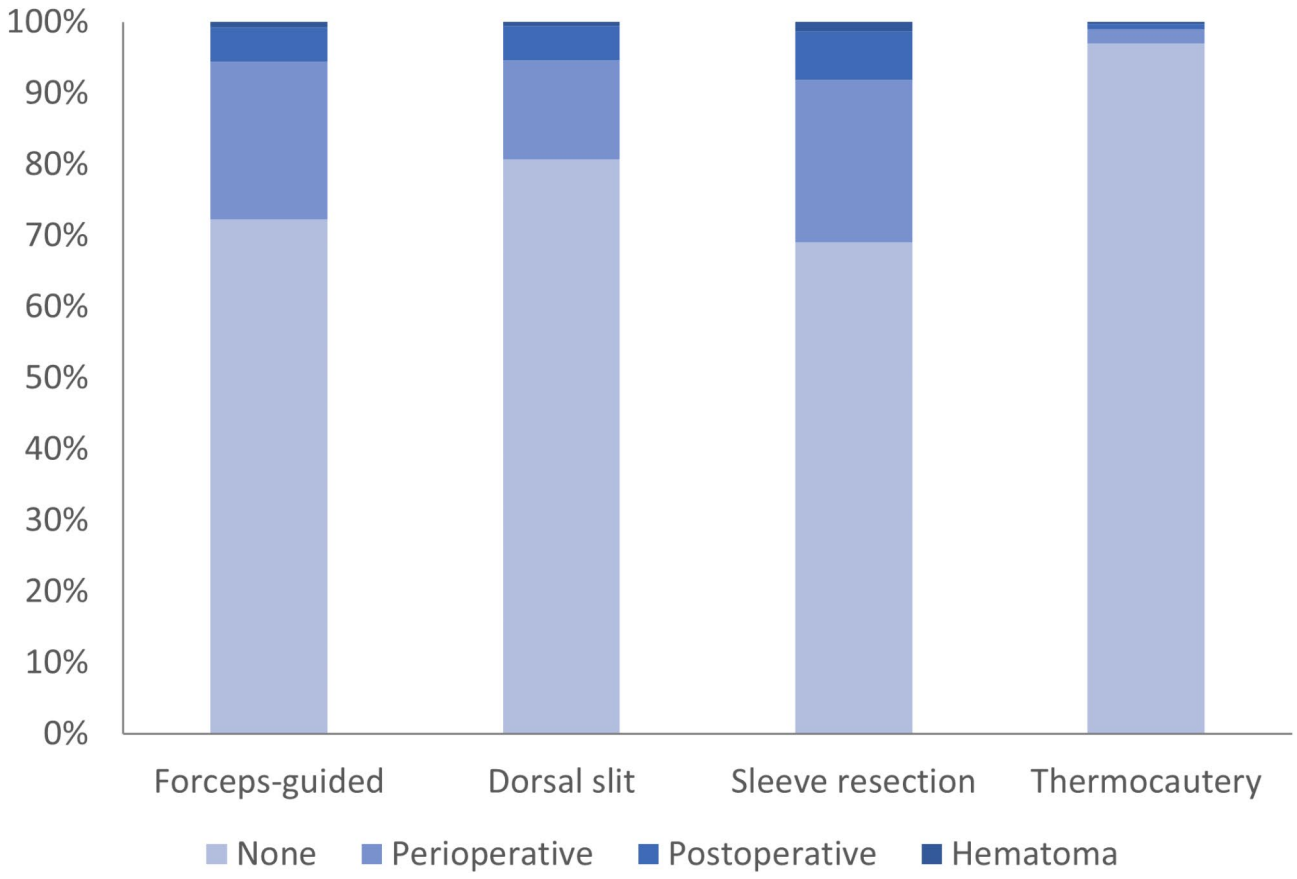

Fig. 3. Rate of bleeding in study groups.

	OR	95% CI		Wald	*p*-value
		LL	UL		
Perioperative bleeding					
Age	0.991	0.977	1.005	1.567	0.211
Subcutaneous ring block	1.542	1.341	1.772	37.140	**< 0.001**
Duration of procedure	0.896	0.877	0.915	104.114	**< 0.001**
Forceps-guided	61.663	42.764	88.913	487.222	**< 0.001**
Dorsal slit	59.249	39.382	89.141	383.613	**< 0.001**
Sleeve resection	161.952	96.100	272.930	364.986	**< 0.001**
Postoperative bleeding					
Age	1.006	0.980	1.033	0.201	0.654
Subcutaneous ring block	0.156	0.113	0.216	125.067	**< 0.001**
Duration of procedure	1.058	1.027	1.089	14.118	**< 0.001**
Forceps-guided	5.175	2.858	9.370	29.452	**< 0.001**
Dorsal slit	4.707	2.356	9.401	19.254	**< 0.001**
Sleeve resection	5.367	2.397	12.020	16.688	**< 0.001**
Hematoma					
Age	0.998	0.933	1.066	0.005	0.942
Subcutaneous ring block	0.605	0.326	1.121	2.552	0.110
Duration of procedure	1.055	1.006	1.106	4.855	**0.028**
Forceps-guided	2.215	0.755	6.501	2.095	0.148
Dorsal slit	1.378	0.300	6.336	0.170	0.680
Sleeve resection	2.923	0.698	12.250	2.153	0.142

Table 4. Effects of conventional circumcision techniques on bleeding compared to TAC, adjusted for other confounding factors – findings of multinominal logistic regression analysis. TAC: thermocautery-assisted circumcision, OR: odds ratio, CI: confidence interval, LL: lower limit, UL: upper limit. The reference category is the group without bleeding. Significant values are in bold.

In one patient who underwent TAC, penile necrosis developed, necessitating the excision of approximately 6 cm^2 of necrotic tissue. A plastic surgeon subsequently used a scrotal flap to cover the affected area. Penile amputation occurred in one patient who underwent the FG technique. This case was urgently referred to a specialized center for microscopic replantation. Late complications in this case included urethral meatus stenosis. Methemoglobinemia occurred in four patients under one year of age. Methemoglobinemia is characterized by elevated blood hemoglobin levels containing oxidized ferric (+3) iron instead of ferrous (+2) iron. Common causes include cocaine-derivative anesthetics such as lidocaine. These patients, monitored in intensive care, were treated with methylene blue. This complication, attributed to local anesthetic use during circumcision, was successfully managed with the assistance of pediatric health consultations.

Discussion

When circumcision is performed under appropriate conditions by experienced physicians, complication rates are significantly low. The technique employed and the practitioner's expertise are critical factors affecting the likelihood of complications. This study, by analyzing a large cohort of cases involving technically similar procedures, namely TAC and CCTs, provides a broad overview of clinical outcomes and early complications. It highlights the advantages of TAC, such as shorter duration of the procedure and reduced postoperative bleeding, as well as its disadvantages, including longer recovery time and postoperative edema.

The most frequently observed early complication of circumcision performed using traditional methods is bleeding. Bleeding and hematomas typically occur due to failure to control frenular vessels or, less commonly, overlooked dorsal vessels. Most post-circumcision bleeding can be managed by applying pressure dressings, i.e., direct pressure[11]. Rarely, wound exploration, hematoma evacuation, and suturing are necessary[12]. In the current study, the incidence of postoperative bleeding was found to be lower in the TAC group compared to the FG, SR, and DS groups. The literature supports the low rates of bleeding associated with circumcision performed using TAC. While postoperative bleeding was less frequent with TAC, the requirement for surgical evacuation of hematomas under anesthesia was comparable to other techniques. Differences in the type of energy used for hemostasis and whether the bleeding is localized at a specific focus might account for these variations. In some cases, foci of bleeding may be overlooked or manifest later. A key technical distinction between TAC and FG lies in the instrument used for cutting the foreskin: scalpels are used in FG, while TAC employs thermal energy through a thermocautery device. The energy source for hemostasis may be monopolar or bipolar, with bipolar cauterization being considered safer. However, in classical cauterization, if not applied carefully, the electric current can penetrate deeply, potentially causing vascular damage and even gangrene in the penis[13]. The thermocautery device used in TAC differs from standard electrocautery systems for bleeding control. By utilizing heat instead of a scalpel for incision, TAC facilitates the sealing of blood vessels with heat energy[14].

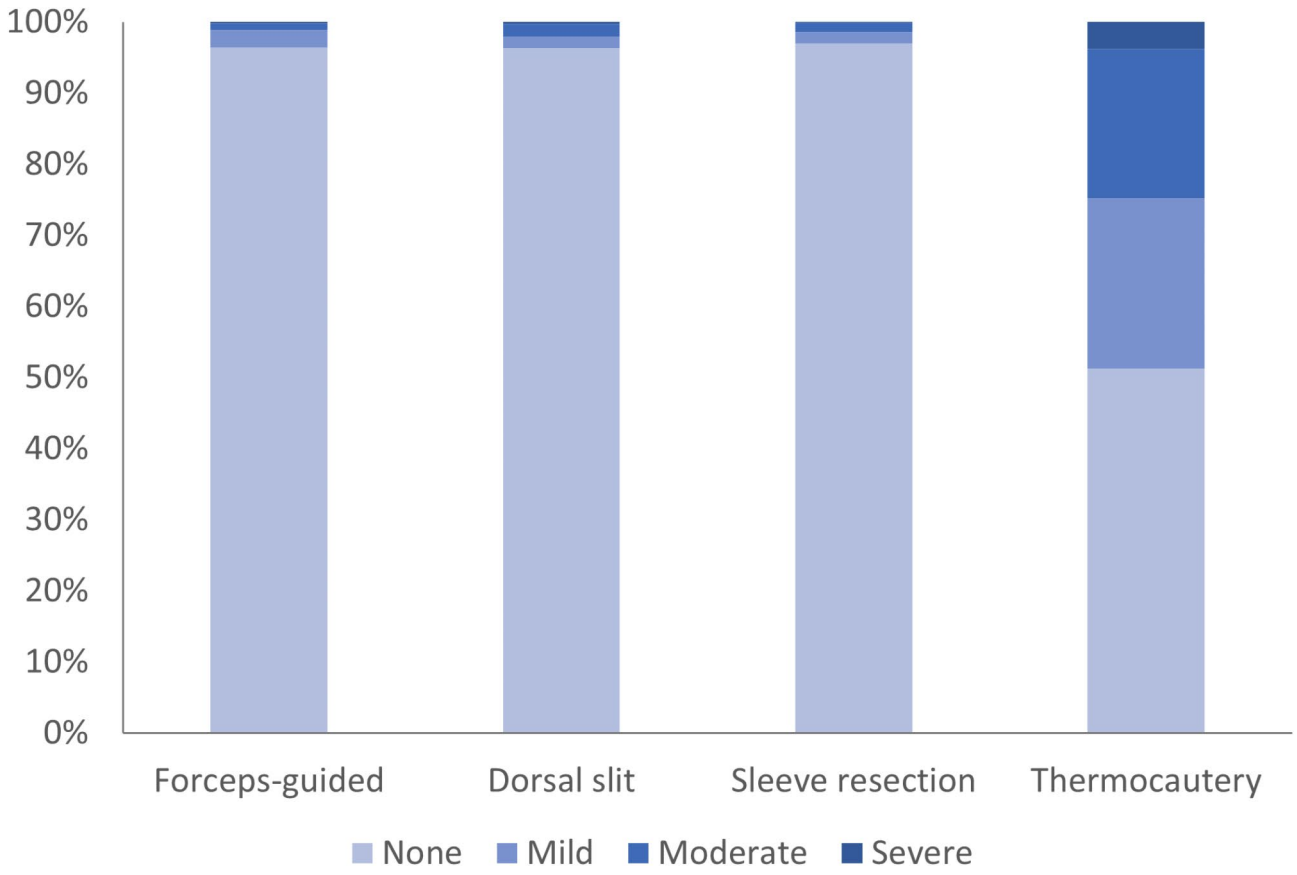

Fig. 4. Rate of edema in study groups.

A study involving a rat model of circumcision compared thermocautery, bipolar cautery, monopolar cautery, and scalpel techniques. The findings indicated that thermocautery resulted in greater collagen proliferation than monopolar devices. Furthermore, the TAC group demonstrated superior epithelialization and less injury depth compared to the bipolar cautery group. Despite the observed histopathological changes, the application of thermocautery for circumcision in rats was deemed safe and led to effective wound healing without complications[15]. In addition, a study evaluating the effects of heat intensity and depth of coagulation necrosis in TAC performed at low and high temperatures reported histopathological results similar to those obtained with a scalpel[9]. TAC has also been considered a useful and cost-effective method for patients with bleeding disorders, as it minimizes the need for factor replacement therapy[16]. In regions where circumcision is not commonly performed in hospitals for socioeconomic reasons, it has been established that TAC can be safely performed when proper equipment and trained personnel are available[17].

Tuncer et al. stated that the TAC, compared to plastic clamping and surgical circumcision, demonstrated lower complication rates and could be comfortably employed both in operating theaters and circumcision clinics[18]. Another study reported that TAC was a safe and effective surgical technique for use in children, demonstrating safety in perioperative, early postoperative, and long-term complications[19]. In reality, in such regions, most circumcisions are performed by non-surgeons in patients' homes. Electrocautery devices are not used, and there is no scientific data on bleeding rates. However, the general belief is that bleeding is minimal. This creates a paradox regarding the role of cauterization in intraoperative bleeding control.

While bleeding is subject to paradoxical interpretations, the greatest challenge and the most commonly associated complication with the new techniques described in recent years is edema. In fact, edema poses a significant problem, particularly within the context of clamp-based circumcision techniques. The edema in clamp circumcisions arises due to the obstruction of lymphatic drainage channels located between the inner and outer plates of the foreskin and the cavernous body[20]. In TAC, increased local hypervascular permeability caused by heat-induced trauma along the circumcision line is proposed as a potential cause of edema. The literature lacks standardized criteria for assessing edema severity. However, edema management is linked to its severity. In the current study, edema quantification was based on the time required for its resolution. Severe cases of edema, despite the use of bandages and creams, could take over 10 days to resolve, posing a prolonged management challenge for both patients and surgeons. We observed that postoperative edema was higher in the TAC group. The literature presents varying results concerning edema in TAC, which may be attributed to the lack of optimal temperature settings and standardization for TAC devices, as well as the absence of objective criteria for assessing this complication. Non-optimal thermocauterization may cause edema along the suture line[21]. In our clinical experience, the edema observed with TAC can sometimes cause anxiety in children and

	OR	95% CI		Wald	*p*-value
		LL	UL		
Mild					
Age	1.026	1.001	1.051	4.162	**0.041**
Subcutaneous ring block	1.355	1.131	1.623	10.830	**<0.001**
Duration of procedure	0.980	0.939	1.023	0.829	0.363
Forceps-guided	0.068	0.038	0.121	83.247	**<0.001**
Dorsal slit	0.040	0.017	0.092	57.199	**<0.001**
Sleeve resection	0.043	0.015	0.124	33.988	**<0.001**
Moderate					
Age	1.015	0.984	1.046	0.861	0.353
Subcutaneous ring block	6.756	5.415	8.430	286.203	**<0.001**
Duration of procedure	0.878	0.824	0.936	16.106	**<0.001**
Forceps-guided	0.068	0.030	0.155	40.634	**<0.001**
Dorsal slit	0.137	0.053	0.353	17.001	**<0.001**
Sleeve resection	0.244	0.061	0.975	3.986	**0.046**
Severe					
Age	0.954	0.895	1.018	1.996	0.158
Subcutaneous ring block	5.113	3.292	7.941	52.786	**<0.001**
Duration of procedure	1.057	1.018	1.097	8.501	**0.004**
Forceps-guided	0.010	0.004	0.027	79.814	**<0.001**
Dorsal slit	0.017	0.004	0.077	28.151	**<0.001**
Sleeve resection	0.005	0.001	0.038	24.564	**<0.001**

Table 5. Effects of conventional circumcision techniques on edema severity compared to TAC, adjusted for other confounding factors –findings of multinominal logistic regression analysis. TAC: thermocautery-assisted circumcision, OR: odds ratio, CI: confidence interval, LL: lower limit, UL: upper limit. The reference category is the group without edema. Significant values are in bold.

their families. Prospective controlled studies with newer energy modalities and optimal device temperature settings may help identify the best approach for incisions[22,23].

Particular attention should be given to pure local anesthesia in neonates and infants due to complications associated with general anesthesia[24]. The circumcision procedure should be completed before the anesthetic effect wears off[6]. In our study, circumcision performed with TAC was found to be shorter in duration, whereas SR required the longest procedure time among the four techniques compared. Cases involving penile block anesthesia with lidocaine and epinephrine were excluded, as the combination has been reported to cause necrosis or ischemia in the penis[25]. The younger age of the patients in the TAC group can be attributed to the consideration of both the child's and the family's psychological expectations, as well as the preference to keep the procedure relatively brief. Efforts have been made to develop techniques to minimize the duration of the procedure and bleeding in circumcision. Age is also a critical factor in complication management. While circumcision is generally performed during childhood for religious reasons, adult circumcision may be conducted in some regions for medical or other personal preferences[26,27]. Although complications overlap to some extent, issues such as wound dehiscence due to erection and infection are more commonly encountered in adults[28,29]. Due to the excellent blood supply of the penis, wound infections are rare[30]. In this study, although the infection rate was higher in the FG group than in the TAC group, no significant differences were found in other pairwise comparisons. The recovery time for circumcision typically ranges between five and 10 days. Interestingly, our study found that the mean healing time was five days, though it was longer in the TAC group and shorter in the SR group compared to the remaining techniques. This could be attributed to histopathological tissue changes induced by the heat energy in TAC and the more precise anatomical cutting with minimal tissue trauma in SR. It is evident that advancements in technical modifications for circumcision will lead to significant improvements in managing these types of complications[31–33].

In this study, non-surgical bleeding, infections, and edema were managed successfully without hospital admissions through outpatient medical treatments and pressure dressings. Regardless of whether circumcision is performed for medical, traditional, or religious purposes, it may rarely result in complications that are difficult to treat. Advanced surgical techniques, including hematoma evacuation and revision, must be known. Rare but life-threatening or organ-compromising complications have been reported in the literature[34]. These rare complications must be meticulously treated and managed by highly specialized practitioners[35–38]. In this study, rare complications were successfully managed with consultations from experts and other specialties.

Limitations

Patient selection for the techniques was not randomized but rather based on the clinical experience and preferences of the surgeons, introducing selection bias. The retrospective nature of the study may have contributed to bias

	OR	95% CI		Wald	*p*-value
		LL	UL		
Mild					
Age	1.004	0.969	1.040	0.043	0.835
Subcutaneous ring block	1.583	1.139	2.200	7.475	**0.006**
Duration of procedure	0.935	0.885	0.987	5.987	**0.014**
Forceps-guided	4.022	1.902	8.507	13.265	**<0.001**
Dorsal slit	2.514	0.978	6.459	3.663	0.056
Sleeve resection	6.198	1.851	20.756	8.753	**0.003**
Moderate					
Age	0.986	0.919	1.058	0.152	0.697
Subcutaneous ring block	1.617	0.880	2.972	2.398	0.122
Duration of procedure	1.015	0.922	1.118	0.092	0.761
Forceps-guided	0.436	0.107	1.782	1.334	0.248
Dorsal slit	0.997	0.209	4.756	0.000	0.997
Sleeve resection	0.757	0.085	6.782	0.062	0.804
Severe					
Age	0.999	0.895	1.116	0.000	0.988
Subcutaneous ring block	0.844	0.323	2.202	0.120	0.729
Duration of procedure	1.078	1.029	1.130	10.062	**0.002**
Forceps-guided	0.272	0.072	1.027	3.690	0.055
Dorsal slit	0.444	0.077	2.568	0.823	0.364
Sleeve resection	0.222	0.033	1.514	2.359	0.125

Table 6. Effects of conventional circumcision techniques on infection severity according to TAC, adjusted for other confounding factors –findings of multinominal logistic regression analysis. TAC: thermocautery-assisted circumcision, OR: odds ratio, CI: confidence interval, LL: lower limit, UL: upper limit. The reference category is the group without infection. Significant values are in bold.

	Forceps-guided (*n* = 3,209)	Dorsal slit (*n* = 611)	Sleeve resection (*n* = 708)	TAC (*n* = 2,513)	*p*-value [1]
0	2,803 (87.3)^{A}	440 (72.0)^{B}	640 (90.4)^{C}	1,841 (73.3)^{B}	<0.001
1	371 (11.6)^{A}	165 (27.0)^{B}	63 (8.9)^{C}	646 (25.7)^{B}	
2	23 (0.7)^{A}	2 (0.3)^{A}	2 (0.3)^{A}	16 (0.6)^{A}	
3a	7 (0.2)^{A}	1 (0.2)^{A}	2 (0.3)^{A}	9 (0.4)^{A}	
3b	4 (0.1)$^{A, B}$	3 (0.5)^{A}	1 (0.1)$^{A, B}$	1 (0.040)^{B}	
4	1 (0.031)^{A}	0 (0.0)^{A}	0 (0.0)^{A}	0 (0.0)^{A}	

Table 7. Frequency distribution of Clavien-Dindo scores within study groups. TAC: thermocautery-assisted circumcision. Descriptive statistics are presented as number (%) of cases[1]. Pearson's χ^2 test. $^{A–C}$No statistically significant differences between the groups with the same upper-case letters ($p > 0.05$).

in the pre-existing outcomes. Additional limitations included the lack of long-term follow-up data, the inability to standardize the classification of subjective endpoints (e.g., edema and infection), and challenges in ensuring inter-observer reliability.

Conclusion

Although there is no significant difference in major complications, TAC demonstrates advantages over CCTs in terms of reduced bleeding and shorter duration of the procedure. However, it also presents disadvantages, such as postoperative edema and longer recovery times. The clinical outcomes and complications of these techniques can assist physicians in selecting the most appropriate method based on each patient's profile.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.Data is provided within the manuscript or supplementary information files.

Received: 14 November 2024; Accepted: 24 February 2025
Published online: 28 February 2025

References

1. Elsayed, B. et al. Estimates of the prevalence of male circumcision in sub-Saharan Africa from 2010-2023—A systematic review and meta-analysis. *PloS One* **19**, e0298387. https://doi.org/10.1371/journal.pone.0298387 (2024).
2. Wahyudi, I., Raharja, P. A. R., Situmorang, G. R. & Rodjani, A. Circumcision reduces urinary tract infection in children with antenatal hydronephrosis: Systematic review and meta-analysis. *J. Pediatr. Urol.* **19**, 66–74. https://doi.org/10.1016/j.jpurol.2022.10.029 (2023).
3. Özkidik, M. et al. Concealed penis after circumcision: Is it beneficial in lowering uropathogenic colonization in penile skin and preventing recurrence of febrile urinary tract infections?? *Urol. J.* **17**, 164–168. https://doi.org/10.22037/uj.v0i0.5192 (2020).
4. Farley, T. M. et al. Impact of male circumcision on risk of HIV infection in men in a changing epidemic context—systematic review and meta-analysis. *J. Int. AIDS. Soc.* **23**, e25490. https://doi.org/10.1002/jia2.25490 (2020).
5. Yao, X., Zhang, G., Xiong, Q., Feng, S. & Liu, X. Plastic clamp versus conventional surgical dissection technique in pediatric circumcision: A systematic review and meta-analysis. *Curr. Urol. Rep.* **25**, 173–180. https://doi.org/10.1007/s11934-024-01209-5 (2024).
6. Uysal, M. & Şanlı, A. Circumcision with thermocautery after local anesthesia in males: A retrospective Single-center study with 1821 patients. *Urol. J.* **19**, 221–227. https://doi.org/10.22037/uj.v19i.6748 (2022).
7. Iacob, S. I., Feinn, R. S. & Sardi, L. Systematic review of complications arising from male circumcision. *BJUI Compass* **3**, 99–123. https://doi.org/10.1002/bco2.123 (2022).
8. J Krill, A., S Palmer, L. & S Palmer, J. Complications of circumcision. *Sci. World J.* **11**, 2458–2468. https://doi.org/10.1100/2011/373829 (2011).
9. Akyüz, O. & Tatar, Z. Is it safe to use a thermocautery device for circumcision? Examination of the histopathological changes emerging after thermocautery-assisted circumcisions. *Andrologia* **53**, e13968. https://doi.org/10.1111/and.13968 (2021).
10. Sağır, S. & Köse, E. Ö. Ç. Subcutaneous ring block and dorsal penile nerve block effectiveness in male circumcision: A cross-sectional study. *Acad. J. Health Sci. Med. Balear* **39**, 74–78. https://doi.org/10.3306/AJHS.2024.39.04.74 (2024).
11. Jiang, W. et al. A modified pressure dressing to avoid severe bleeding after circumcision with a disposable circumcision suture device and a discussion on the mechanism of bleeding with the disposable circumcision suture device. *Sex. Med.* **9**, 100288. https://doi.org/10.1016/j.esxm.2020.100288 (2021).
12. Mano, R., Nevo, A., Sivan, B., Morag, R. & Ben-Meir, D. Post-ritual circumcision bleeding-characteristics and treatment outcome. *Urology* **105**, 157–162. https://doi.org/10.1016/j.urology.2017.03.038 (2017).
13. Uzun, G., Ozdemir, Y., Eroglu, M. & Mutluoglu, M. Electrocautery-induced gangrene of the glans penis in a child following circumcision. *BMJ Case Rep.* (2012). https://doi.org/10.1136/bcr-2012-007096 (2012).
14. Olcucu, M. T. & Teke, K. Evaluation of Short-term postoperative complications according to the Clavien-Dindo classification system in thermocautery-assisted circumcision cases. *J. Urol. Surg.* **7**, 218–227. https://doi.org/10.4274/jus.galenos.2020.3266 (2020).
15. Tuncer, A. A. et al. Examination of histopathological changes of scalpel, monopolar, bipolar, and thermocautery applications in rat experimental circumcision model. *Am. J. Transl. Res.* **9**, 2306–2313 (2017).
16. Karaman, M. I., Zulfikar, B., Caskurlu, T. & Ergenekon, E. Circumcision in hemophilia: A cost-effective method using a novel device. *J. Pediatr. Surg.* **39**, 1562–1564. https://doi.org/10.1016/j.jpedsurg.2004.06.025 (2004).
17. Arslan, D., Kalkan, M., Yazgan, H., Ünüvar, U. & Şahin, C. Collective circumcision performed in Sudan: Evaluation in terms of early complications and alternative practice. *Urology* **81**, 864–867. https://doi.org/10.1016/j.urology.2012.11.070 (2013).
18. Tuncer, A. A. & Erten, E. E. A. Examination of short and long term complications of thermocautery, plastic clamping, and surgical circumcision techniques. *Pak. J. Med. Sci.* **33**, 1418–1423. https://doi.org/10.12669/pjms.336.13640 (2017).
19. Tuncer, A. A. & Deger, M. Incidence of complications following thermocautery-assisted circumcisions. *Urol. J.* **15**, 359–364. https://doi.org/10.22037/uj.v15i6.4296 (2018).
20. Wang, D., Li, Z., Chen, X. & Wang, H. Wound healing rates and wound problems of conventional circumcision compared with ring circumcision: A meta-analysis. *Int. Wound J.* **20**, 3699–3707. https://doi.org/10.1111/iwj.14262 (2023).
21. Gozukucuk, A., Cakiroglu, B. & Tas, T. The comparison of surgical and thermocautery-assisted techniques used in neonatal circumcision. *Medicine* **11**, 593–597. https://doi.org/10.5455/medscience.2021.10.353 (2022).
22. Zeng, F., Cao, Q., Fu, F., Wang, B. & Sun, Z. Biological welding: A rapid and bloodless approach to circumcision. *World J. Urol.* **43**, 25. https://doi.org/10.1007/s00345-024-05355-w (2024).
23. Scarcella, S. et al. Does using a laser improve outcomes of conventional circumcision in adult and children populations? Results from a systematic review and meta-analysis. *Andrology* **11**, 54–64. https://doi.org/10.1111/andr.13321 (2023).
24. Kılıç, S. Comparative analysis of two methods in circumcision: A new disposable device versus classic sleeve technique. *BMC Urol.* **24**, 126. https://doi.org/10.1186/s12894-024-01513-9 (2024).
25. Gul, M., Kaynar, M., Sekmenli, T., Ciftci, I. & Goktas, S. Epinephrine injection associated scrotal skin necrosis. *Case Rep. Urol.* **2015**, 187831. https://doi.org/10.1155/2015/187831 (2015).
26. Rosato, E., Miano, R., Germani, S. & Asimakopoulos, A. D. Phimosis in adults: Narrative review of the new available devices and the standard treatments. *Clin. Pract.* **14**, 361–376. https://doi.org/10.3390/clinpract14010028 (2024).
27. Mu, J., Fan, L., Liu, D. & Zhu, D. A. Comparative study on the efficacy of four types of circumcision for elderly males with redundant prepuce. *Urol. J.* **17**, 301–305. https://doi.org/10.22037/uj.v0i0.4973 (2020).
28. Chou, A. C., Laih, C. Y. & Ku, F. Y. A retrospective Taiwanese-population-based clinical study on determining the efficacy and safety of disposable circumcision anastomat. *J. Clin. Med.* **11**. https://doi.org/10.3390/jcm11206206 (2022).
29. Shabanzadeh, D. M., Clausen, S., Maigaard, K. & Fode, M. Male circumcision Complications—a systematic review, meta-analysis and meta-regression. *Urology* **152**, 25–34. https://doi.org/10.1016/j.urology.2021.01.041 (2021).
30. Khalil, A., Hamid, E., Siddiq, K. & Hassan, M. Methicillin-resistant *Staphylococcus aureus* urosepsis: A rare complication of neonatal circumcision. *SAGE Open. Med. Case Rep.* **8**, 2050313x20966122. https://doi.org/10.1177/2050313x20966122 (2020).
31. Rao, J. M. et al. Modified circumcision using the disposable circumcision suture device in children: A randomized controlled trial. *Urology* **143**, 206–211. https://doi.org/10.1016/j.urology.2020.06.018 (2020).
32. Li, M. et al. A modified disposable circumcision suture device with application of plastic sheet to avoid severe bleeding after circumcision. *Urol. J.* **19**, 152–156. https://doi.org/10.22037/uj.v19i.6977 (2022).
33. Su, Q. et al. A comparative study on the clinical efficacy of modified circumcision and two other types of circumcision. *Urol. J.* **18**, 556–560. https://doi.org/10.22037/uj.v16i7.6193 (2020).
34. Schröder, A., Farhat, W. A., Chiasson, D., Wilson, G. J. & Koyle, M. A. Serious and fatal complications after neonatal circumcision. *Eur. Urol. Focus* **8**, 1560–1563. https://doi.org/10.1016/j.euf.2021.12.005 (2022).
35. Schifano, N. et al. Glans ischaemia after circumcision in adult males: A two-patient case series and a narrative review of the literature. *Urologia* **91**, 852–860. https://doi.org/10.1177/03915603241273611 (2024).
36. Petrella, F., Amar, S., El-Sherbiny, M. & Capolicchio, J. P. Total glans amputation after neonatal circumcision. *Urol. Case Rep.* **37**, 101624. https://doi.org/10.1016/j.eucr.2021.101624 (2021).
37. Haşegan, A. et al. Severe acute ischemia of Glans penis after achieving treatment with only hyperbaric oxygen therapy: A rare case report and systematic literature review. *J. Personal. Med.* **13**. https://doi.org/10.3390/jpm13091370 (2023).
38. Ouattara, A. et al. Complications of non-medical assisted circumcision in Burkina Faso. Clinical presentation, management, and outcomes—about 23 cases and literature review. *Archivio Italiano Di Urol. Andrologia: Organo Ufficiale [di] Soc. [di]taliana Di Ecografia Urologica E Nefrologica* **95**, 11494. https://doi.org/10.4081/aiua.2023.11494 (2023).

Author contributions
The conceptual aspects of this work were collaborated upon by all authors. Other contributions include data acquisition by B.K., K.T., and M.T.Ö.; data analysis and interpretation by B.K., S.S., and C.B.; drafting of manuscript by B.K., A.Ç., and M.Ö.Y.; critical revision of the manuscript for scientific and factual content by A.Ç., B.K., and M.Ö.Y., and statistical analysis by B.K.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations

Competing interests
The authors declare no competing interests.

Ethics statement
This retrospective chart review study involving human participants was conducted in accordance with the ethical standards of the institutional and national research committees, as well as the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. It was approved by the Scientific Research Permit Commission of the Ağrı Provincial Health Directorate (meeting date: July 8, 2021, decision number: 60).

Consent to participate
Informed consent was obtained from all individual participants included in the study.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-91730-5.

Correspondence and requests for materials should be addressed to B.K.