Trans-oral robotic surgery versus coblation tongue base reduction for obstructive sleep apnea syndrome

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Objectives. To compare the efficacy of trans-oral robotic surgery (TORS) with that of coblation assisted tongue base reduction surgery in patients with obstructive sleep apnea syndrome (OSAS). **Subjects and Methods.** The medical charts were retrospectively reviewed for all OSAS patients admitted to one institution for surgical intervention between 2012 and 2017. We analyzed 33 cases; 16 patients received TORS and 17 received coblation surgery for tongue base reduction. Both groups received concomitant uvulopalatoplasty. Surgical outcomes were evaluated by comparing the initial polysomnography (PSG) parameters with the follow-up PSG data (at least 3 months after the surgery). Epworth sleepiness scale (ESS) and complications were also compared between the 2 groups. **Results.** The success rate (≥50% reduction of pre-operative AHI and post-operative AHI <20) in the TORS group and coblation group were 50% and 58%, respectively, and there was no significant difference (p= .611). The AHI (mean ± SD) reduction in the TORS and coblation groups were 24.9±26.5 events/h and 19.4±24.8 events/h, respectively; the between-group difference was not significant (p= .631). ESS improvement did not differ significantly between the TORS and coblation groups (3.8±6.6 and 3.1±9.2, respectively, p= .873). The rates of minor complication were higher in the TORS group (50%) than that of the coblation group (35.3%) without statistical significance (p= .393). **Conclusion.** TORS achieved comparable surgical outcomes compared to coblation assisted tongue base reduction surgery in OSAS patients. Multilevel surgery using either TORS or coblation tongue base reduction combi ned with uvulopalatoplasty is an effective approach for the managementof OSAS.

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2 **Obstructive Sleep Apnea Syndrome**

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19   **Abstract**

21   **Objectives.** To compare the efficacy of trans-oral robotic surgery (TORS) with that of

22   coblation assisted tongue base reduction surgery in patients with obstructive sleep

23   apnea syndrome (OSAS).

24   **Subjects and Methods.** The medical charts were retrospectively reviewed for all OSAS

25   patients admitted to one institution for surgical intervention between 2012 and 2017. We

26   analyzed 33 cases; 16 patients received TORS and 17 received coblation surgery for

27   tongue base reduction. Both groups received concomitant uvulopalatoplasty. Surgical

28   outcomes were evaluated by comparing the initial polysomnography (PSG) parameters

29   with the follow-up PSG data (at least 3 months after the surgery). Epworth sleepiness

30   scale (ESS) and complications were also compared between the 2 groups.

31   **Results.** The success rate ($\geqq$50% reduction of pre-operative AHI and post-operative

32   AHI <20) in the TORS group and coblation group were 50% and 58%, respectively, and

33   there was no significant difference (p= .611). The AHI (mean ± SD) reduction in the

34   TORS and coblation groups were 24.9±26.5 events/h and 19.4±24.8 events/h,

35   respectively; the between-group difference was not significant (p= .631). ESS

36   improvement did not differ significantly between the TORS and coblation groups (3.8±6.6

37   and 3.1±9.2, respectively, p= .873). The rates of minor complication were higher in the

38   TORS group (50%) than that of the coblation group (35.3%) without statistical

39   significance (p= .393).

40   **Conclusion.** TORS achieved comparable surgical outcomes compared to coblation

41   assisted tongue base reduction surgery in OSAS patients. Multilevel surgery using either

42   TORS or coblation tongue base reduction combined with uvulopalatoplasty is an

43   effective approach for the management of OSAS.

44

45   **Introduction**

46   Obstructive sleep apnea syndrome (OSAS) is a common disorder which affects 3-7% of

47   adult men and 2-5% of adult women.(Punjabi 2008) OSAS results from upper airway

48   collapse during sleep. Clinical symptoms include fragmented sleep and excessive

49   daytime sleepiness.(Semelka, Wilson et al. 2016) Continuous positive airway pressure

50   (CPAP) is thought to be the gold standard treatment for OSAS,(Lucia Spicuzza 2015) but

51   some patients cannot tolerate it and may seek surgical treatment instead.(Kotecha and

52   Hall 2014) Different levels and degrees of obstruction in OSAS patients lead to variable

53   response to surgical intervention.(Koutsourelakis, Safiruddin et al. 2012) In one study,

54   Vroego et al. analyzed the upper airway collapse patterns in patients with sleep-

55   disordered breathing by using drug-induced sleep endoscopy (DISE) and multilevel

56   collapse was disclosed in 68.2% of all patients.(Vroegop, Vanderveken et al. 2014) As

57   the intricacies of airway collapse are better understood, due to improvements in

58   diagnostic and evaluative methods, multilevel surgery is becoming a more common

59   method of successfully treating OSAS.(Thaler, Rassekh et al. 2016, Lin, Friedman et al.

60   2017) Among these patients with multilevel collapse, the most frequently seen pattern

61   was the concomitant collapse of palatal and tongue base (25.5%).(Vroegop,

62   Vanderveken et al. 2014) Uvulopalatopharyngoplasty (UPPP) is the most commonly

63   reported surgery to address oropharyngeal obstruction. For dealing with tongue base

64   obstruction, trans-oral robotic surgery (TORS) and coblation assisted tongue base

65   reduction surgery were two of the most published tongue base tissue reduction

66   procedures.

67

68   Several preoperative assessment strategies have been used. The Friedman tonsil

69   grading scale classifies the tonsil size into five grades (grade 0-IV) according to the

70   location the tonsil relative to the surrounding structures.(Friedman, Tanyeri et al. 1999)

71   The Friedman tongue position (FTP) grading system is evaluated similarly to the

72   modified Mallampati classification, but the tongue is evaluated in a neutral position

73 without protrusion. The Friedman staging system incorporates FTP, Friedman tonsil

74 grading scale and BMI to classify OSAS patients into four stages: stage I includes

75 patients with tonsils graded III-IV, FTP graded I-II and BMI<40 kg/M^2; stage III includes

76 patients with tonsils graded 0-II, FTP graded III-IV and BMI<40 kg/M^2; stage IV includes

77 patients with BMI>40 kg/M^2 or significant craniofacial or other anatomic abnormalities;

78 stage II includes patients beyond stage I, III, IV.(Friedman, Salapatas et al. 2017)

79 Fiberoptic nasopharyngoscopy with Muller's maneuver, which mimics the

80 pathophysiological status of OSAS during wakefulness by asking the patient to block

81 bilateral nostrils and inhale with mouth closed, can identify the level and degree of upper

82 airway collapse.(Terris, Hanasono et al. 2000) Drug-induced sleep endoscopy (DISE),

83 which is recognized as a breakthrough in evaluation of OSAS patients, can provide direct

84 identification of airway collapse during intravenous anesthesia. The VOTE classification

85 is utilized for the findings of DISE.(Kezirian, Hohenhorst et al. 2011)

86

87 For most patients with oropharyngeal obstruction, uvulopalatopharyngoplasty (UPPP) is

88 one of the most common and effective surgical procedures.(Khan, Ramar et al. 2009)

89 However, oropharyngeal obstruction combined with tongue base obstruction is

90 recognized as an important reason for failure after pharyngoplasty procedures.(Choi,

91   Cho et al. 2016) For tongue base obstruction, multiple procedures have been proposed

92   and could be simply categorized into tongue base volume reduction and tongue

93   suspension. Among these procedures, trans-oral robotic surgery (TORS) and coblation

94   assisted tongue base reduction surgery proved to be the most published therapeutic

95   methods in the field of tongue base reduction.(Cammaroto, Montevecchi et al. 2017)

96   TORS can provide a 3D visual field and the operator can easily access the tongue base

97   area and perform surgery using delicately controlled robotic instruments. Nevertheless,

98   the high cost of TORS makes operators and patients hesitant touse   it.(Cammaroto,

99   Montevecchi et al. 2017) Endoscopic coblation assisted tongue base reduction surgery

100   has been reported to be a useful procedure for tongue base obstruction and it has a

101   lower cost compared to TORS.(Friedman, Hamilton et al. 2012, Li, Lee et al. 2016)

102   However, there is a lack of fair comparison studies regarding the treatment efficacy and

103   safety between TORS and coblation assisted tongue base reduction. Therefore, this

104   study was conducted to compare the subjective and objective outcomes of TORS with

105   endoscope-guided coblation tongue base reduction.

106

107   **Materials and methods**

108   Medical charts were retrospectively reviewed for OSAS patients admitted for TORS or

109   coblation tongue base reduction surgery to a single tertiary hospital between 2012 and

110   2017. 33 patients with age ranging from 18 to 62 years met the inclusion criteria (Table

111   1). Patients who were excluded were those without available postoperative

112   polysomnography (PSG) data. PSG was performed at 3-12 months after the surgery.

113   Patients who had previous upper airway surgery for OSAS were also excluded. This

114   study was approved by the Institutional Review Board of the China Medical University

115   Hospital (project approval number CMUH103-REC1-078).

116

117   Detailed profiles were constructed for each patient and included the following variables:

118   age, sex, body mass index (BMI), tonsil grade, Friedman tongue position, Friedman

119   stage, pre-operative and post-operative Epworth sleepiness scale (ESS). Post-operative

120   ESS was recorded at the date for post-operative PSG. Nasopharyngoscopy with Muller's

121   maneuver and drug-induced sleep endoscopy (DISE) were performed in all patients to

122   evaluate the site of obstruction and the pattern of the airway collapse. The grades of

123   airway collapse in Muller's maneuver were divided into four grades according to the

124   percentage change in cross-sectional area: grade I $\leqq$25% collapse, grade II $>$25% and

125    $\leqq$50% collapse, grade III $>$50% and $\leqq$75% collapse, grade IV >75% collapse. VOTE

126   classification was utilized for reporting DISE findings and the grade of collapse were

127   classified as 0 (<50% obstruction); 1 (50–75% obstruction) and 2 (>75% obstruction).

128   Patients undergoing surgery must have at least partial tongue base collapse confirmed

129   by Muller's maneuver and DISE. Details were also recorded from pre-operative and

130   post-operative PSG data, and included AHI, apnea index (AI), lowest oxygen saturation

131   (min-SpO2), and cumulative time percentage with SpO2 <90% (CT90) (Table 2). The

132   success of the surgery was defined as achievement of $\geqq$ 50% reduction of pre-operative

133   AHI and a post-operative AHI <20. Perioperative parameters, including the length of stay

134   in hospital, the numeric rating scale (NRS) assessment on the first postoperative day for

135   pain intensity and complications, were recorded.

136

137   In this study, 16 patients received TORS and 17 patients received coblation surgery for

138   tongue base reduction. All patients received conventional uvulopalatopharyngoplasty

139   combined with tongue base reduction for multilevel obstruction in these patients.

140   All of the surgeries were performed by a single surgeon.

141

142   The surgical procedure of trans-oral robotic surgery for tongue base volume reduction

143   was performed similar to the previous published literature.(Vicini, Dallan et al. 2010,

144   Friedman, Hamilton et al. 2012) General anesthesia was introduced via nasotracheal

145   intubation. The anesthesia machine was positioned at the left side foot of the bed. The

146   surgical cart of the da Vinci surgical system (Intuitive Surgical, Sunnyvale, California,

147   USA) approached the patient from the right-hand side with an angle of 45 degrees to the

148   bed. The scrub nurse stood next to the patient's left hand and the first assistant sat at the

149   head of the bed. The operative surgeon was at the operative console and used open-

150   surgery hand movements which were precisely replicated in the operative field by the

151   robotic instruments. The laryngeal advanced retractor system (Fentex, Tuttlingen,

152   Germany) was used to expose the tongue base area. The size of the tongue blade was

153   chosen accordingly to well expose the tongue base. Under 30 degree 3D camera

154   endoscope, tongue base tissue was grasped by robotic forceps and cauterized with

155   spatula monopolar electrode. The midline posterior glossectomy began from the

156   foramen cecum and advanced posteriorly to vallecula without injury to epiglottis mucosa,

157   laterally to 1cm from the midline and 1.5 cm inferior to the tongue base surface.

158

159   Endoscopic coblation assisted tongue base reduction surgery was performed similar to

160   previous reports.(Wee, Tan et al. 2015, Li, Lee et al. 2016) Under general anesthesia

161   with nasotracheal intubation, the Molt mouth gag (Sklar, West Chester, Pennsylvania,

162   USA) was applied to the left side of labial commissure. We placed a silk suture through

163   the anterior tongue and the silk was held by a Kelly forceps. The first assistant could

164   easily retract the tongue forward by holding the Kelly forceps. A 70 degree rigid

165   endoscope (Karl Storz, Tuttlingen, Germany) was applied to expose the tongue base

166   area and kept in position by an endoscope holder (Karl Storz, Tuttlingen, Germany).

167   With the aid of the endoscope holder, the surgeon could perform the procedure

168   bimanually and thus decrease the operation time and the morbidity related to blood loss.

169   The Coblator II ENT Surgery System and PROCISE MAX coblation wand (Arthrocare

170   ENT, Sunnyvale, California, USA) were used for the midline posterior glossectomy. The

171   targeted resection area was the same as the TORS mentioned above.

172

173   We used the Statistical Packages for the Social Sciences version 24.0 (IBM Corp.;

174   Armonk, NY, USA) for statistical analysis of the data. The descriptive statistic was used

175   to present the outcome values. The Mann-Whitney and signed Wilcoxon test were used

176   for comparing numerical variables between and within groups, respectively. Fisher's

177   exact test was used for categorical variables. A p value of less than .05 was considered

178   to be statistically significant.

179

180   **Result**

181 Among the 33 patients in this analysis, 16 were of the TORS group (age of 39.4±12.3

182 years; mean ± SD) and 17 patients were of the coblation group (age of 38.7±11.5 years,

183 mean ± SD). Male comprised 93.8% in the TORS group and 76.5% in the coblation

184 group. The mean body mass index (BMI) at the time of admission was 28.2±3.8 kg/m^2 in

185 the TORS group and 27.4±5.6 kg/m^2 in the coblation group. There were no significant

186 differences in tonsil grading scale, Friedman tongue position and Friedman staging

187 system between the two groups before surgery. The grades of collapse in Muller's

188 maneuver and DISE were similar in both groups. The mean Epworth sleepiness scale

189 (ESS) was 11.1±4.7 in the TORS group and 10.9±5.2 in the coblation group. All patients

190 received polysomnography (PSG) for pre-operative evaluation. The mean baseline

191 apnea-hyponea index (AHI) was 50.5±19.6 events/h and mean apnea index (AI) was

192 33.3±19.2 events/h in the TORS group; corresponding values were 44.9±28.8 events/h

193 and 31.3± 26.8events/h, respectively, in the coblation group. The mean lowest oxygen

194 saturation (min-SpO2) was 73.8±6.8% and mean cumulative time percentage with

195 SpO2<90% (CT90) was 15.1±14.5% in the TORS group; corresponding values were

196 74.0±10.0% and 13.1±15.3% in the coblation group. Demographics and baseline PSG

197 data for both groups are summarized in Table 2. There were no significant between-

198 group differences prior to treatment.

199

200 The comparisons within-group (Table 3) and between-group (Table 4) were analyzed,

201 respectively.Statistically significant improvement of ESS was observed in both groups.

202 ESS (mean ± SD) improvement did not differ significantly between the TORS and

203 coblation groups (3.4±3.1 and 2.8±4.4, respectively, p= .646; 95% CI= -3.30–2.08,

204 Figure 2). The AHI (mean ± SD) reduced significantly from 50.5±19.6 events/h to

205 25.5±19.5 events/h in the TORS group (p= .002). In the coblation group, the mean AHI

206 reduced significantly from 44.8±28.8 events/h to 25.5±23.3 events/h (p= .005). The AHI

207 reduction in the TORS and coblation groups were significantly reduced, and the

208 between-group difference was not significant (p= .631; 95% CI=-12.67–23.73, Figure 3

209 and 4).The mean AI reduced significantly in both TORS and coblation group (p= .014and

210 p= .004, respectively), but the mean AI reduction did not differ significantly between the

211 groups as well (p= .657; 95% CI=-18.53–14.60, Figure 4). The mean min-SpO2

212 improved from 73.8±6.8% to 83.8±5.6% (p= .001) in the TORS group and from

213 74.0±10.0% to 80.7±12.6% in the coblation group (p= .045). The mean improvement of

214 min-SpO2 was 10.0±7.7% in the TORS group and 6.7±12.6% in the coblation group.

215 There were no statistically significant differences in the improvement of min-SpO2

216 between the two groups (p= .363; 95% CI= -4.11–10.82, Figure 5). The TORS group

217   patients had a greater reduction in CT90 percentage, but the difference was not

218   significant. The success rate in the TORS group and coblation group were 50% and 58%,

219   respectively, and there was no statistically significant difference (p= .611; 95% CI=-4.93–

220   13.79, Figure 5).

221

222   The mean numeric rating scales (NRS) for pain evaluation on the first postoperative day

223   were similar in both groups (TORS group = 2.8± 0.9; coblation group = 2.5 ± 0.7; p= .533).

224   In the TORS group, the length of stay in hospital was longer compared with the coblation

225   group (p= .002). There were no major complications (e.g., intra-operative or post-

226   operative bleeding, airway compromise, prolonged intubation, pneumonia and

227   pharyngeal laceration, tongue limitation) in either group. No tracheotomies were

228   performed for airway management perioperatively. The rates of minor complication,

229   including transient dysphagia, pharyngeal edema and dysgeusia, in the TORS and

230   coblation groups were 8/16 (50%) and 6/17(35.3%), respectively.

231

232   **Discussion**

233   Our results presented that the surgical outcomes of trans-oral robotic surgery (TORS)

234   were comparable to coblation assisted tongue base reduction surgery in obstructive

235   sleep apnea syndrome (OSAS) patients. The PSG outcomes and success rate were

236   similar for the TORS and coblation groups.

237

238   Multilevel surgery is thought to be more effective than UPPP for management of patients

239   suffering from OSAS. Because of the better understanding of the complexity of the upper

240   airway collapse during sleep in OSAS patients, surgeons can determine correct surgical

241   management according to the site of obstruction and the pattern of the airway

242   collapse.(Toh, Han et al. 2014, Li, Lee et al. 2016, Thaler, Rassekh et al. 2016)

243

244   In a retrospective study, 25 moderate-to-severe OSAS patients with retropalatal and

245   tongue base obstruction received coblation endoscopic lingual lightening and modified

246   uvulopalatopharyngoplasty (relocation pharyngoplasty). AHI (mean ± SD) decreased

247   significantly from 45.7±21.7 to 12.8±8.2 events/hour (p<.001) postoperatively and the

248   overall surgical success rate was 80%.(Li, Lee et al. 2016) The Coblation lingual tonsil

249   removal technique proved to be an effective procedure in a cohort of Korean OSAS

250   patients with retroglossal obstruction. The mean AHI decreased significantly from

251   37.7±18.6 to 18.7±14.8 events/hour (p<.001) and the success rate was 55.6%.(Wee,

252   Tan et al. 2015) Another study compared combined coblation endoscopic lingual

253   lightening and relocation pharyngoplasty to relocation pharyngoplasty alone in OSAS

254   patients (AHI>20, Friedman stage III), and reported that combined surgery had better

255   improvement in AHI (-65.5 vs -53.2; p=.047) and higher surgical success rate than

256   relocation pharyngoplasty alone (73% vs 50%; p=.04).(Li, Lee et al. 2016)

257

258   O'Malley et al. developed a minimally invasive surgical procedure for management of

259   tongue base neoplasms by using robotic surgical instruments.(O'Malley, Weinstein et al.

260   2006) Trans-oral robotic surgery (TORS) can offer clear 3D visualization and gain

261   adequate access to tongue base, larynx and hypopharynx and provide meticulous tissue

262   resection. A preliminary study in 2010 conducted by Vicini et al. reported that TORS for

263   tongue base resection in OSAS patients is practical and well tolerated. Ten patients were

264   included and the AHI (mean ± SD) decreased from 38.3±23.5 to 20.6±17.3

265   events/hour.(Vicini, Dallan et al. 2010) Further study for demonstration of the feasibility

266   of TORS performed in forty four patients with OSAS reported significant improvement of

267   mean AHI (24.6±22.2 events/hour) and mean ESS (5.9±4.4).(Vicini, Dallan et al. 2012)

268   The latest systematic review and meta-analysis by Meccariello et al. concluded that

269   TORS seems to be a promising and safe technology for the management of OSAS and

270   the mean failure rate was 34.4% (29.5–46.2%).(Meccariello, Cammaroto et al. 2017)

271

272   A study by Friedman et al. in 2012 was thought to be the first comparative study for

273   comparison of coblation and TORS in OSAS treatment.(Friedman, Hamilton et al. 2012)

274   It compared the effectiveness of TORS with that of coblation assisted submucosal

275   minimally invasive lingual excision (SMILE). All the patients in the study received

276   concomitant z-palatoplasty. The AHI (mean ± SD) reduction in the TORS and SMILE

277   groups were 60.5%±24.9% and 32.0% ± 43.3% (p = .012), respectively. The success

278   rate in the TORS and SMILE groups were 66.7% and 45.5%, respectively; the between-

279   group difference was not significant (p= .135). However, the techniques used by each

280   group were different and not completely comparable.

281

282   To the best of our knowledge, there is few finely matched studies regarding the

283   treatment efficacy and safety between TORS and coblation adopting similar technique in

284   tongue base resection. Our retrospective comparison of TORS with coblation in the

285   treatment of OSAS patients with multilevel obstruction found that both groups had similar

286   surgical results.

287

288   The demographics and preoperative polysomnographic data did not differ significantly

289   between the two groups (Table 2) at baseline. According to the within-group outcomes

290   showed in Table 3, statistically significant improvement of apnea-hyponea index (AHI),

291   apnea index (AI), Epworth Sleepiness scale (ESS) and minimum oxygen saturation (min-

292   SpO2) were noted in both the TORS and coblation groups. It confirmed that either TORS

293   tongue base resection or coblation assisted tongue base resection combined with

294   concomitant uvuolopalatoplsty can offer reliable surgical results. The cumulative time

295   percentage with SpO2 < 90% (CT90) were decreased in both groups but only

296   significantly reduced in the TORS group which could be related to small sample size or

297   poor correlation of CT90 to AHI.(Chung, Liao et al. 2012)

298

299   As detailed in Table 4, the mean reduction of AHI, AI, ESS, CT90 and mean

300   improvement of min-SpO2 were similar for the TORS and coblation groups. The rate of

301   surgical success in the TORS group were comparable to the coblation group (50% vs

302   58%, p= .611). Hwang et al. compared the tongue base coblation resection to TORS in

303   OSAS patients and both groups were in combination with lateral pharyngoplasty.(Hwang,

304   Kim et al. 2017) They reported that the surgical success rates did not differ significantly

305   between the two groups (56.3% in TORS vs 62.1% in coblation, p= .711). Our success

306   rates are lower than those in that study. However, the preoperative BMI of patients in

307 that study was lower than in our study group (TORS group = 28.2± 3.8 kg/m², coblation

308 group = 27.4 ±5.6 kg/m², p = .645).. Moreover, preoperative mean ESS were lower

309 (TORS group = 11.1 ± 4.7; coblation group = 10.9 ± 5.2, p = .917)   and mean min-SpO2

310 were higher (TORS group = 73.8 ± 6.8 %; coblation group = 74.0± 10.0 %, p = .951) in

311 their study than those in our study group, which might suggest the severity of OSAS

312 is greater in our patients. In our study, the mean pain scores (numeric rating scales) on

313 the first postoperative day were comparable in both groups (TORS group = 2.8± 0.9;

314 coblation group = 2.5 ± 0.7; p = .533). In the TORS group, the length of stay in hospital

315 was longer compared with the coblation group (p= .002). There was no major

316 complication in either group. The rates of minor complication were higher in the TORS

317 group (50%) than that of the coblation group (35.3%) without statistical significance.

318 According to a review article, slightly better outcomes were observed in TORS compared

319 to coblation, but the higher rate of minor complications and the significant costs of TORS

320 are two aspects which surgeons will need to consider.(Cammaroto, Montevecchi et al.

321 2017)

322

323 This study has some limitations. First, the retrospective analysis used in this study is a

324 possible source for selection bias by patients' preferences even after shared decision

325   makings and routine surgical treatment strategy explanation. Second, it is difficult to

326   make comparisons among studies because of different surgical techniques utilized by

327   TORS (e.g. midline posterior glossectomy(Lin, Rowley et al. 2015), lingual

328   tonsillectomy(Muderris, Sevil et al. 2015)) and coblation (e.g. midline posterior

329   glossectomy(Li, Lee et al. 2016), SMILE(Friedman, Soans et al. 2008), channelling of

330   the tongue(Zhang and Liu 2014), Interstitial injections with needle coblation(Hou, Hu et

331   al. 2012)). Third, non-parametric approach is that we are unable to adjust for potential

332   confounders. In the future, prospective, randomized, controlled trials that incorporate

333   similar surgical technique will be needed to evaluate the efficacy of TORS compared with

334   coblation tongue base reduction. Moreover, studies providing long-term results in the

335   treatment of OSAS are also warranted.

336

337   **Conclusion**

338   TORS resulted in comparable objective and subjective outcomes compared to coblation

339   assisted tongue base reduction surgery in OSAS patients. Multilevel surgery with either

340   TORS or coblation tongue base reduction combined with uvulopalatoplasty is effective in

341   reducing disease severity in moderate-to-severe OSAS cases.

342

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348

References

350   Cammaroto, G., F. Montevecchi, G. D'Agostino, E. Zeccardo, C. Bellini, B. Galletti, M. Shams, H.
351   Negm and C. Vicini (2017). "Tongue reduction for OSAHS: TORSs vs coblations, technologies vs
352   techniques, apples vs oranges." Eur Arch Otorhinolaryngol **274**(2): 637-645.
353   Choi, J. H., S. H. Cho, S. N. Kim, J. D. Suh and J. H. Cho (2016). "Predicting Outcomes after
354   Uvulopalatopharyngoplasty for Adult Obstructive Sleep Apnea: A Meta-analysis." Otolaryngol
355   Head Neck Surg **155**(6): 904-913.
356   Chung, F., P. Liao, H. Elsaid, S. Islam, C. M. Shapiro and Y. Sun (2012). "Oxygen desaturation
357   index from nocturnal oximetry: a sensitive and specific tool to detect sleep-disordered
358   breathing in surgical patients." Anesth Analg **114**(5): 993-1000.
359   Friedman, M., C. Hamilton, C. G. Samuelson, K. Kelley, D. Taylor, K. Pearson-Chauhan, A. Maley,
360   R. Taylor and T. K. Venkatesan (2012). "Transoral robotic glossectomy for the treatment of
361   obstructive sleep apnea-hypopnea syndrome." Otolaryngol Head Neck Surg **146**(5): 854-862.
362   Friedman, M., A. M. Salapatas and L. B. Bonzelaar (2017). "Updated Friedman Staging System
363   for Obstructive Sleep Apnea." Adv Otorhinolaryngol **80**: 41-48.
364   Friedman, M., R. Soans, B. Gurpinar, H. C. Lin and N. Joseph (2008). "Evaluation of submucosal
365   minimally invasive lingual excision technique for treatment of obstructive sleep
366   apnea/hypopnea syndrome." Otolaryngol Head Neck Surg **139**(3): 378-384; discussion 385.
367   Friedman, M., H. Tanyeri, M. La Rosa, R. Landsberg, K. Vaidyanathan, S. Pieri and D. Caldarelli
368   (1999). "Clinical predictors of obstructive sleep apnea." Laryngoscope **109**(12): 1901-1907.
369   Hou, T., S. Hu and X. Jiang (2012). "Tongue coblation via the ventral approach for obstructive
370   sleep apnea-hypopnea syndrome surgery." Laryngoscope **122**(11): 2582-2586.
371   Hwang, C. S., J. W. Kim, J. W. Kim, E. J. Lee, C. H. Kim, J. H. Yoon and H. J. Cho (2017).

372 "Comparison of robotic and coblation tongue base resection for obstructive sleep apnoea." Clin

373 Otolaryngol.

374 Kezirian, E. J., W. Hohenhorst and N. de Vries (2011). "Drug-induced sleep endoscopy: the VOTE

375 classification." Eur Arch Otorhinolaryngol **268**(8): 1233-1236.

376 Khan, A., K. Ramar, S. Maddirala, O. Friedman, J. F. Pallanch and E. J. Olson (2009).

377 "Uvulopalatopharyngoplasty in the management of obstructive sleep apnea: the mayo clinic

378 experience." Mayo Clin Proc **84**(9): 795-800.

379 Kotecha, B. T. and A. C. Hall (2014). "Role of surgery in adult obstructive sleep apnoea." Sleep

380 Med Rev **18**(5): 405-413.

381 Koutsourelakis, I., F. Safiruddin, M. Ravesloot, S. Zakynthinos and N. de Vries (2012). "Surgery

382 for obstructive sleep apnea: sleep endoscopy determinants of outcome." Laryngoscope **122**(11):

383 2587-2591.

384 Li, H. Y., L. A. Lee and E. J. Kezirian (2016). "Coblation endoscopic lingual lightening (CELL) for

385 obstructive sleep apnea." Eur Arch Otorhinolaryngol **273**(1): 231-236.

386 Li, H. Y., L. A. Lee and E. J. Kezirian (2016). "Efficacy of Coblation Endoscopic Lingual Lightening

387 in Multilevel Surgery for Obstructive Sleep Apnea." JAMA Otolaryngol Head Neck Surg **142**(5):

388 438-443.

389 Lin, H.-C., M. Friedman, H.-W. Chang, L. Bonzelaar, A. M. Salapatas, M.-C. Lin and K.-T. Huang

390 (2017). "Minimally Invasive, Single-Stage, Multilevel Surgery for Obstructive Sleep Apnea in

391 Asian PatientsMinimally Invasive Surgery for Obstructive Sleep Apnea in Asian

392 PatientsMinimally Invasive Surgery for Obstructive Sleep Apnea in Asian Patients." JAMA

393 Otolaryngology–Head & Neck Surgery **143**(2): 147-154.

394 Lin, H. S., J. A. Rowley, A. J. Folbe, G. H. Yoo, M. S. Badr and W. Chen (2015). "Transoral robotic

395 surgery for treatment of obstructive sleep apnea: factors predicting surgical response."

396 Laryngoscope **125**(4): 1013-1020.

397 Lucia Spicuzza, D. C. a. G. D. M. (2015). "Obstructive sleep apnoea syndrome and its

398 management." Ther Adv Chronic Dis **6**(5): 273-285.

399 Meccariello, G., G. Cammaroto, F. Montevecchi, P. T. Hoff, M. E. Spector, H. Negm, M. Shams, C.

400 Bellini, E. Zeccardo and C. Vicini (2017). "Transoral robotic surgery for the management of

401 obstructive sleep apnea: a systematic review and meta-analysis." Eur Arch Otorhinolaryngol

402 **274**(2): 647-653.

403 Muderris, T., E. Sevil, S. Bercin, F. Gul and M. Kiris (2015). "Transoral robotic lingual

404 tonsillectomy in adults: preliminary results." Acta Otolaryngol **135**(1): 64-69.

405 O'Malley, B. W., Jr., G. S. Weinstein, W. Snyder and N. G. Hockstein (2006). "Transoral robotic

406 surgery (TORS) for base of tongue neoplasms." Laryngoscope **116**(8): 1465-1472.

407 Punjabi, N. M. (2008). "The epidemiology of adult obstructive sleep apnea." Proc Am Thorac Soc

408 **5**(2): 136-143.

409 Semelka, M., J. Wilson and R. Floyd (2016). "Diagnosis and Treatment of Obstructive Sleep

410 Apnea in Adults." Am Fam Physician **94**(5): 355-360.

411 Terris, D. J., M. M. Hanasono and Y. C. Liu (2000). "Reliability of the Muller maneuver and its

412 association with sleep-disordered breathing." Laryngoscope **110**(11): 1819-1823.

413 Thaler, E. R., C. H. Rassekh, J. M. Lee, G. S. Weinstein and B. W. O'Malley, Jr. (2016). "Outcomes

414 for multilevel surgery for sleep apnea: Obstructive sleep apnea, transoral robotic surgery, and

415 uvulopalatopharyngoplasty." Laryngoscope **126**(1): 266-269.

416 Toh, S. T., H. J. Han, H. N. Tay and K. L. Kiong (2014). "Transoral robotic surgery for obstructive

417 sleep apnea in Asian patients: a Singapore sleep centre experience." JAMA Otolaryngol Head

418 Neck Surg **140**(7): 624-629.

419 Vicini, C., I. Dallan, P. Canzi, S. Frassineti, M. G. La Pietra and F. Montevecchi (2010). "Transoral

420 robotic tongue base resection in obstructive sleep apnoea-hypopnoea syndrome: a preliminary

421 report." ORL J Otorhinolaryngol Relat Spec **72**(1): 22-27.

422 Vicini, C., I. Dallan, P. Canzi, S. Frassineti, A. Nacci, V. Seccia, E. Panicucci, M. Grazia La Pietra, F.

423 Montevecchi and M. Tschabitscher (2012). "Transoral robotic surgery of the tongue base in

424 obstructive sleep Apnea-Hypopnea syndrome: anatomic considerations and clinical

425 experience." Head Neck **34**(1): 15-22.

426 Vroegop, A. V., O. M. Vanderveken, A. N. Boudewyns, J. Scholman, V. Saldien, K. Wouters, M. J.

427 Braem, P. H. Van de Heyning and E. Hamans (2014). "Drug-induced sleep endoscopy in sleep-

428 disordered breathing: report on 1,249 cases." Laryngoscope **124**(3): 797-802.

429 Wee, J. H., K. Tan, W. H. Lee, C. S. Rhee and J. W. Kim (2015). "Evaluation of coblation lingual

430 tonsil removal technique for obstructive sleep apnea in Asians: preliminary results of surgical

431 morbidity and prognosticators." Eur Arch Otorhinolaryngol **272**(9): 2327-2333.

432 Zhang, Q. and D. Liu (2014). "Coblation-channelling for the tongue." Lin Chung Er Bi Yan Hou

433 Tou Jing Wai Ke Za Zhi **28**(6): 386-388.

434

Inclusion criteria

AHI = Apnea-Hypopnea Index; DISE = Drug-Induced Sleep Endoscopy; CPAP = Continuous positive airway pressure

Table 1:

Inclusion criteria

≥ 18 years old
Symptoms of obstructive sleep apnea syndrome (snoring, disrupted sleep, daytime sleepiness)
Preoperative AHI > 10
Friedman tongue position grade 3 or 4
Partial or complete retropalatal and retroglossal collapse in Muller's maneuver and DISE
Cannot tolerate CPAP

AHI = Apnea-Hypopnea Index; DISE = Drug-Induced Sleep Endoscopy; CPAP = Continuous positive airway pressure

Demographics, Baseline data of the 2 groups†

BMI=body mass index (weight in kilograms devided by height in meters squared); FTP = Friedman tongue position; DISE = Drug-Induced Sleep Endoscopy; ESS = Epworth Sleepiness scale; AHI = Apnea-Hypopnea index; AI = Apnea index; Min-SpO2 = minimum oxygen saturation; CT90 = cumulative time percentage with SpO2 < 90% † All values are presented as mean ± standard deviation

TABLE 2.

Demographics, Baseline data of the 2 groups†

	TORS group (n=16)	Coblation group (n=17)	p value
age, years	39.4±12.3	38.7±11.5	.861
Male, n (%)	15 (93.8)	13 (76.5)	.335
BMI, kg/m^2	28.2±3.8	27.4±5.6	.645
Tonsil grade	2.0±1.3	1.9±0.8	.748
FTP	3.4±0.6	3.4±0.6	.918
Friedman stage	2.5±0.6	2.7±0.6	.340
Grade of collapse in Muller maneuver			
Retropalatal area	3.2±0.9	3.6±0.6	.147
Retroglossal area	2.6±0.9	2.3±0.8	.260
Grade of collapse in DISE			
Velum	1.9±0.3	1.8±0.4	.428
Oropharynx	1.5±0.5	1.6±0.5	.624
Tongue base	1.4±0.5	1.5±0.5	.611
Epiglottis	0.5±0.6	0.4±0.5	.460
ESS	11.1±4.7	10.9±5.2	.917
AHI, events/hour	50.5±19.6	44.9±28.8	.517
AI, events/hour	33.3±19.2	31.3±26.8	.816
Min-SpO2, %	73.8±6.8	74.0±10.0	.951
CT90, %	15.1±14.5	13.1±15.3	.705

BMI=body mass index (weight in kilograms devided by height in meters squared); FTP = Friedman tongue position; DISE = Drug-Induced Sleep Endoscopy; ESS = Epworth Sleepiness scale; AHI = Apnea-Hypopnea index; AI = Apnea index; Min-SpO2 = minimum oxygen saturation; CT90 = cumulative time percentage with SpO2 < 90%

† All values are presented as mean ± standard deviation

Within-group comparison of the treatment outcomes†

AHI = Apnea-Hypopnea index; AI = Apnea index; ESS = Epworth Sleepiness scale; Min-SpO2 = minimum oxygen saturation; CT90 = cumulative time percentage with SpO2 < 90%

† All values are presented as mean ± standard deviation * p < .05 is considered statistically significant

TABLE 3.

Within-group comparison of the treatment outcomes†

	TORS group (n = 16)			Coblation group (n = 17)		
	Preoperative	Postoperative	p value	Preoperative	Postoperative	p value
AHI	50.5±19.6	25.5±19.5	.002*	44.8±28.8	25.5±23.3	.005*
AI	33.3±19.2	16.5±17.5	.014*	31.4±26.9	12.7±22.0	.004*
ESS	11.1±4.7	7.6±3.6	< .001*	10.9±5.2	8.1±5.5	.017*
Min-SpO2	73.8±6.8	83.8±5.6	< .001*	74.0±10.0	80.7±12.6	.045*
CT90	15.1±14.5	5.7±7.6	.005*	13.2±15.2	8.2±18.3	.183

AHI = Apnea-Hypopnea index; AI = Apnea index; ESS = Epworth Sleepiness scale; Min-SpO2 = minimum oxygen saturation; CT90 = cumulative time percentage with SpO2 < 90%

† All values are presented as mean ± standard deviation

* p < .05 is considered statistically significant

Between-groups comparison of the treatment outcomes

SD = standard deviation; AHI = Apnea-Hypopnea index; AI = Apnea index; ESS = Epworth Sleepiness scale; Min-SpO2 = minimum oxygen saturation; CT90 = cumulative time percentage with SpO2 < 90%; NRS = numerical rating scale

TABLE 4.

Between-groups comparison of the treatment outcomes

	TORS group (n=16)	Coblation group (n=17)	p value
AHI reduction (events/h)	24.9±26.5	19.4±24.8	.631
AI reduction(events/h)	16.7±23.9	18.7±22.7	.657
ESS reduction	3.8±6.6	3.1±9.2	.873
Min-SpO2 improvement	10.0±7.7	6.7±12.6	.363
CT90 reduction	9.3±11.4	4.9±14.7	.510
Success rate, n (%)	8(50.0)	10(58.8)	.611
Day 1 pain score(NRS)	2.8±0.9	2.5±0.7	.533
Hospital stay (days)	5.5±1.2	4.4±0.7	.004
Major complication, n (%)	0(0)	0(0)	
Minor complication, n (%)	8(50.0)	6(35.3)	.393

AHI = Apnea-Hypopnea index; AI = Apnea index; ESS = Epworth Sleepiness scale; Min-SpO2 = minimum oxygen saturation; CT90 = cumulative time percentage with SpO2 < 90%; NRS = numerical rating scale

Figure 1

The study flow diagram
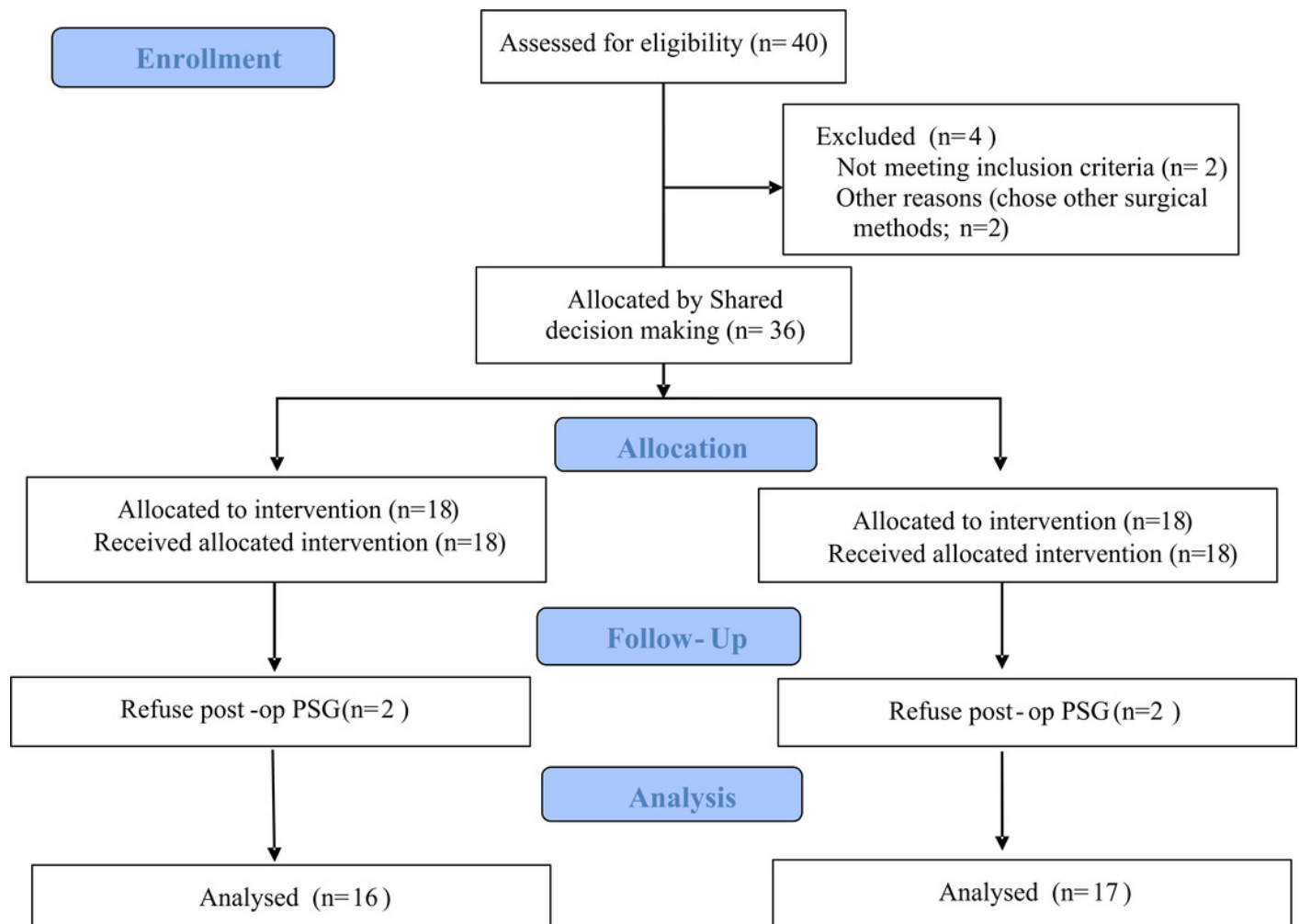
Figure 2

The treatment outcome of ESS between two groups
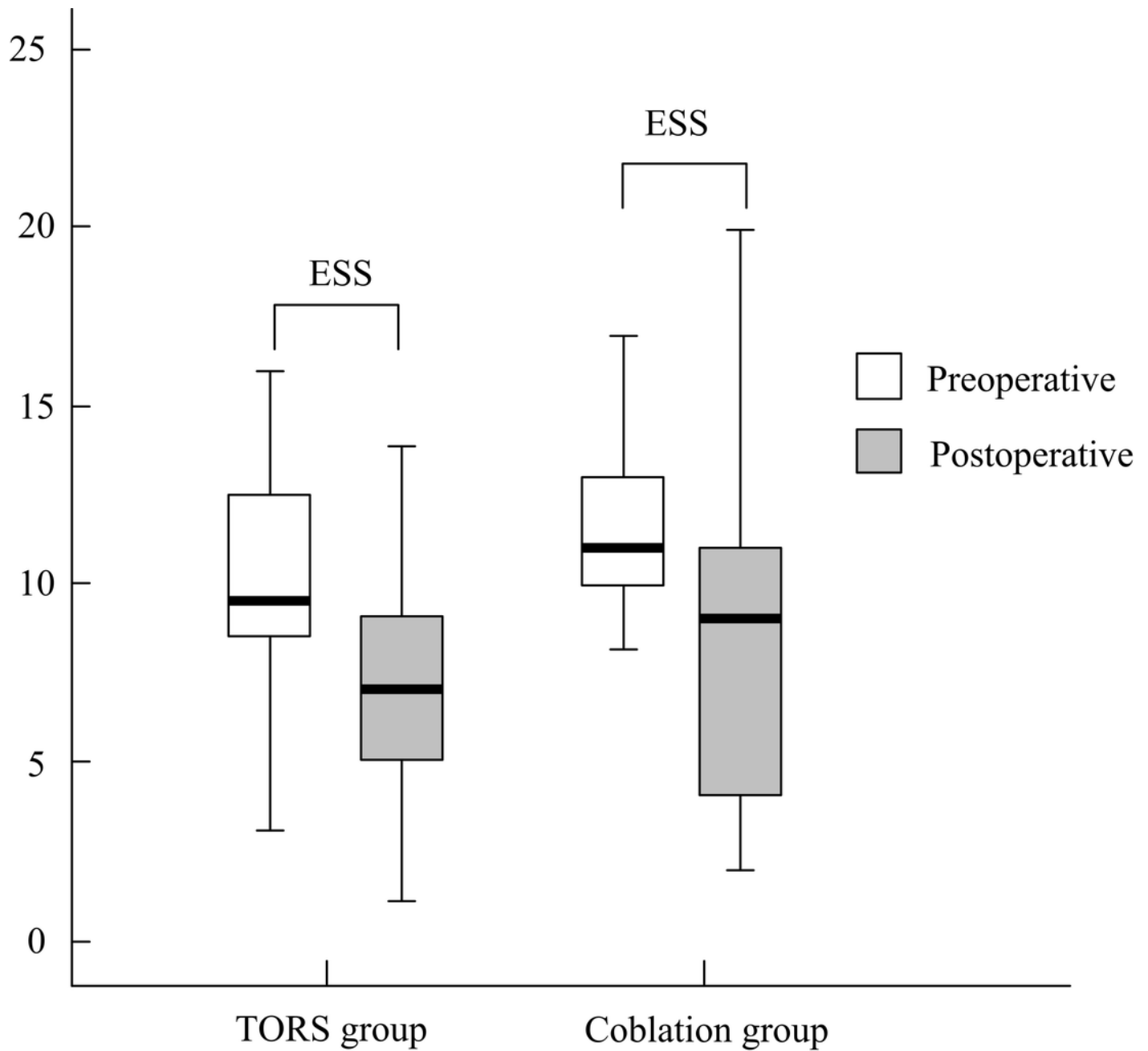
Figure 3

Individual AHI decrease in TORS (A) and Coblation (B) groups
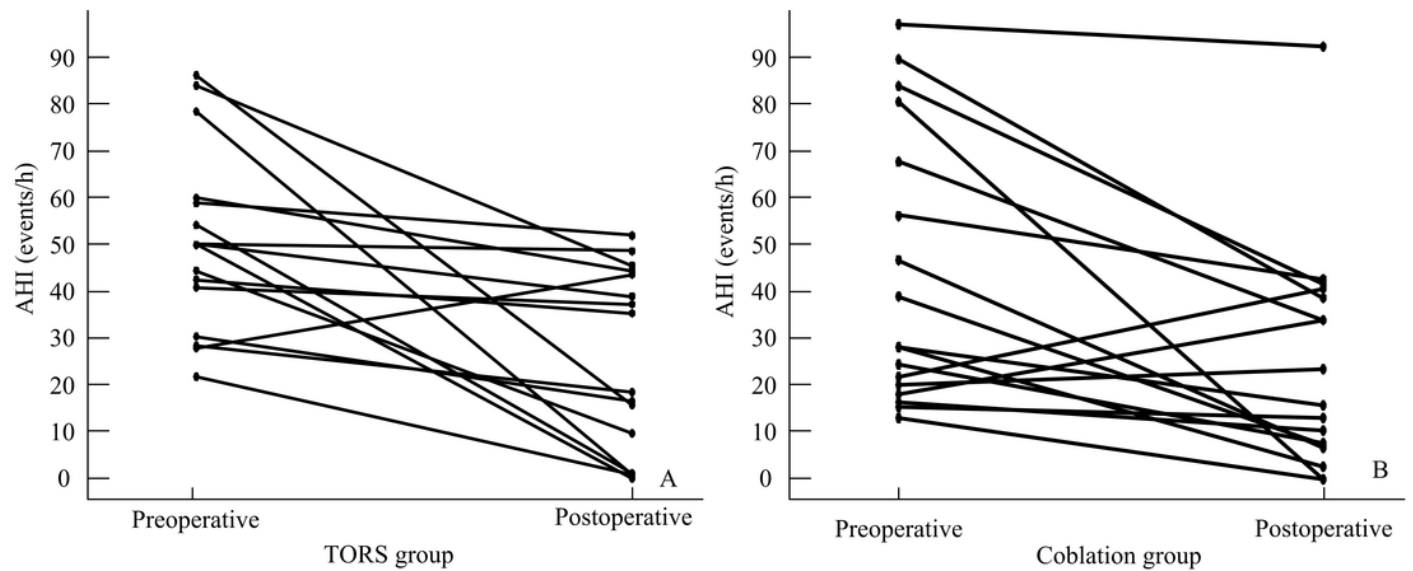
Figure 4

The treatment outcome of AHI and AI between two groups
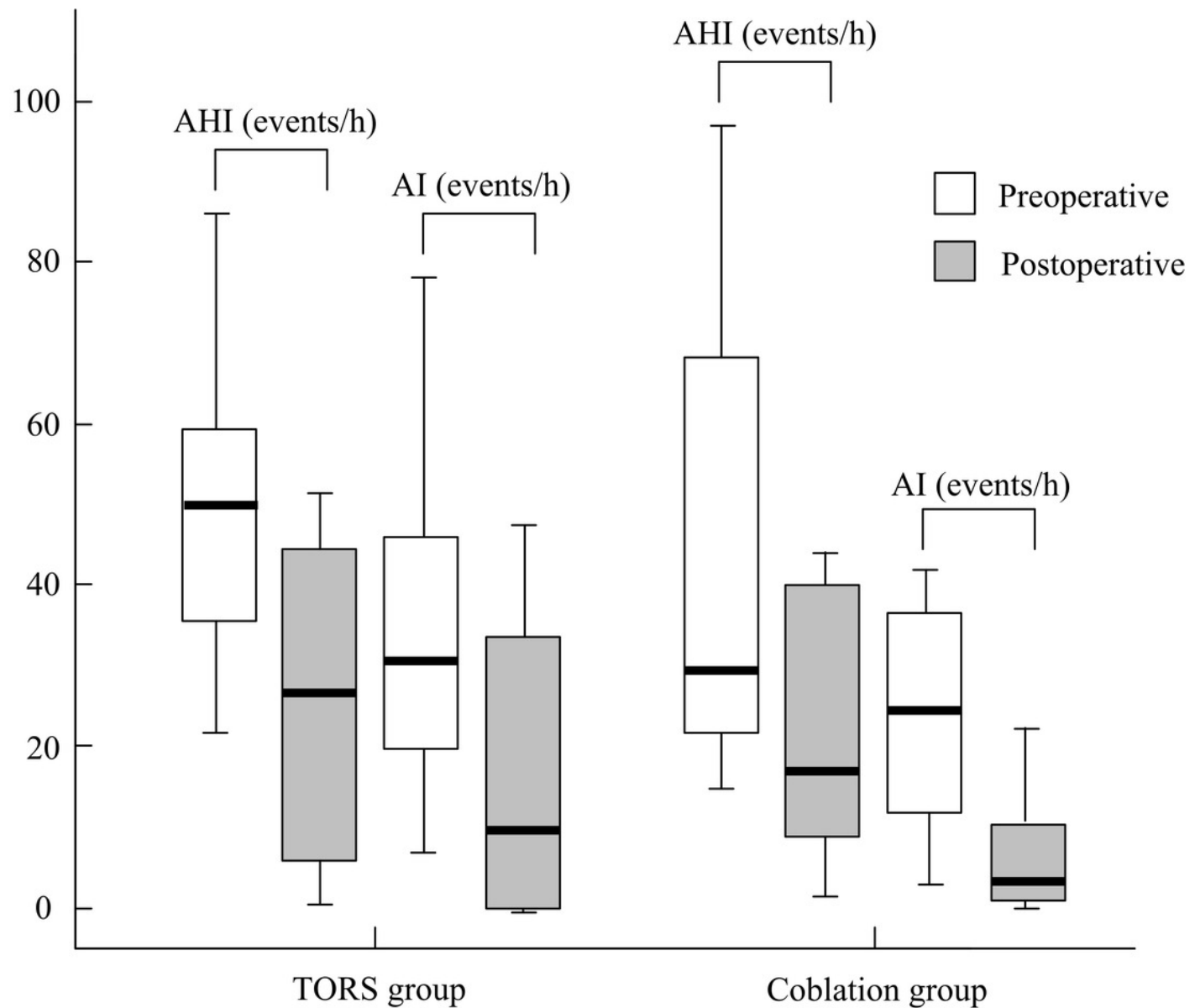
Figure 5

The treatment outcome of min-SpO2 and CT 90 between two groups