# Transcranial Approach versus Endoscopic Transsphenoidal Approach during Midline Suprasellar Meningioma Resection—A Complication and Outcome-Based Study: A Meta-Analysis

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## Abstract

**Background and Purpose**   The choice of surgical approach for the removal of midline suprasellar meningiomas (MSM) has long remained inconclusive among neurosurgeons. While some neurosurgeons prefer transcranial approach (TCA), others favor the use of endoscopic transsphenoidal approach (ETSA). Retrospectively, we assessed the effectiveness of TCA and ETSA on the basis of postoperative outcome and complications to inform future clinical decision making on MSMs.

**Materials and Methods**   A retrospective systematic review and meta-analysis was performed on published case series in PubMed from the year 2000 to 2014. Demographic data, clinical variables, and outcome measures of patients who had their MSMs surgically removed via TCA or ETSA were subjected to rigorous statistical analysis.

**Results**   There were 48 studies with 1,466 patients who underwent TCA (32 studies) and ETSA (16 studies). TCA had a statistically significant rate of tumor recurrence ($p = 0.02$; odds ratio [OR], 1.8; 95% confidence interval [CI], 1.1–6.39) while ETSA had a high rate of CSF leakage ($p = 0.04$; OR, 25; 95% CI, 1.78–11.56). Both TCA and ETSA did not improve visual recovery and gross total resection, but only minimally influenced total clinical outcome.

**Conclusion**   Put together, ETSA and TCA did not improve CSF leakage rate and tumor recurrence respectively, but in the absence of a surgical approach that could maximize the advantages of both TCA and ETSA, it is advisable that neurosurgeons take an informed clinical decision reflective of patient peculiar clinical presentations as well as risk/benefit profile of surgical technique.

**Keywords**
► midline suprasellar meningiomas
► transcranial and endoscopic transsphenoidal approach
► outcomes and meta-analysis

## Introduction

Approximately, 5 to 10% of all intracranial meningiomas are midline suprasellar meningiomas (MSMs)[1] that normally originate from tuberculum sellae (TS), diaphragm sellae (DS), and planum sphenoidale (PS).[2–9] MSMs are benign, slow growing, encapsulated, and normally attached to a part of the dura, falx, or tentorium.[2,10] MSMs exhibit complex symptoms such as adhering to vascular walls or completely engulfing them, however, they typically do not invade blood

vessels. In view of the delicate anatomic location and proximity of MSMs to neurovascular structures (internal carotid artery and its branches, mainly anterior cerebral artery and anterior communicating artery, optic apparatus) and the pituitary gland,[11] they represent a major problem for surgical removal by neurosurgeons. In most cases, visual disturbances secondary to displaced optic apparatus is the main clinical presentation.[12–16] A successful surgical removal of MSM is normally characterized by removal of the tumor along with surrounding dura and associated hyperostotic bone while preserving vision. Postoperation visual recovery or preservation of vision is the gold standard for assessing surgical approaches for MSMs.[7,13,17,18]

Two most commonly used surgical approaches for MSM are the traditional transcranial approach (TCA) or microscopic/ modern endoscopic transsphenoidal approach (ETSA). Neurosurgeons are divided when it comes to the choice of surgical approach for the removal of MSMs. Although some studies have investigated the choice of TCA and TSA for surgical removal of suprasellar meningiomas on the basis of some postoperative outcome measures including visual improvement, cerebrospinal fluid (CSF) leakage, tumor recurrence, and gross total resection (GTR),[19–21] yet the choice problem remains unsolved. This problem has been attributed to many factors including limited studies on the topic, methodological heterogeneity, and small patient numbers as well as biased reporting. For example, case series on meningiomas removed by ETSA series were shown to be small lesions,[22] this gives biased impression of ETSA compared with TCA.

To contribute, the present systematic review retrospectively analyzed published case series on MSMs independently removed by TCA or ETSA. Importantly, this review subjected the data captured in these published studies to rigorous meta-analysis as a means to provide rationale for the choice of surgical techniques for MSM management.

## Methods

### Search Methodology

We searched for data on case series published in PubMed from the year 2000 to 2014. Regarding study design, 32 articles were under transcranial group[5–9,11,13–16,18–21,23–40] and 16 articles were under endoscopic group.[19–22,41–52] The following search terms: meningioma, tuberculum sellae, diaphragm sellae, planum sphenoidale, transcranial, resection, and outcomes were used either singly or in combination. The following approaches: frontotemporal/pterional, unilateral subfrontal, bilateral subfrontal, supraorbital, and interhemispheric were collectively designated as TCA. For the purpose of comparison, similar searches were performed using the terms; endoscopy, endonasal, transsphenoidal, midline suprasellar, tuberculum sellae, diaphragm sellae, and planum sphenoidale meningiomas. Likewise, only endoscope-assisted or microscope- and endoscopic-assisted approaches were collectively designated as ETSA. Data reported in aggregated form were included to report overall pooled rates. The assessment of efficacy of the procedures was based on

surgical outcomes: visual improvement, GTR, and perioperative complications. There was disparity on visual functioning among the case series, mostly between formal visual field testing and subjective patient assessment method; however, both were used as a means to assess visual field in this study. Also, strength of evidence score (SOES) was designed based on a criteria (►Table 1).

### Inclusion and Exclusion Criteria

Only patients with tumor specifically located in the TS, DS, or PS were included in this study. The studies were reviewed and observations were made regarding study design, methodology, and patient characteristics (►Table 2).The cases for each study were extracted and the cohorts assessed based on preoperative clinical features (visual deficits, headache, and endocrinopathy) and postoperative outcomes (visual function, GTR, occurrence of CSF leakage, and tumor recurrence). Similarly, morbidity assessment was based on frequency of infection (pneumonia, meningitis, and wound/bone flap infection), seizure, hemorrhage, visual worsening, endocrinopathy, and anosmia. Information on mortality, if available, was captured. Age was categorized into $\leq 50$ or $> 50$ years. Tumor size was categorized into $\leq 2.4$ or $> 2.4$ cm. Also, duration of symptoms was categorized into $\leq 12$ or $> 12$ months. The $p$-values $\leq 0.05$ were considered statistically significant in all analysis. Duplication of patients was eliminated in case series where multiple papers were published by the same authors or the same institution. In such situations, only reports with the largest sample size and relevant data were selected.

Table 1 Strength of evidence scoring (SOES) system demonstrating the assignment of scores based on visual assessment, demographic variables (sex, mean age, size, and volume of tumor, and volume of tumor resection) in patients that were operated for MSM

| Included variable | SOES |
|---|---|
| 10 or more patients<br>Postoperative vision assessment<br>Nonvisual complication<br>Reported age, sex, size, or volume or extent of resection | 1 |
| 10 or more patients<br>Postoperative vision assessment OR<br>Nonvisual complication<br>Reported age, sex, size, or volume or extent of resection | 2 |
| 10 or more patients<br>Postoperative vision assessment OR<br>Nonvisual complication OR<br>2 of 3 (reported age sex, size, or volume or extent of resection) | 3 |
| Either 10 or more patients OR<br>Postoperative vision assessment OR<br>Nonvisual complication OR<br>1of 3 (reported age, sex, size, or volume or extent of resection) | 4 |

Abbreviation: MSM, midline suprasellar meningioma; OR, odds ratio.

**Table 2** Extracted articles with their demographic variables

| Author/year | Study location | Surgery | Year of surgery | Total no. of cases | Mean age in years (range) | No. of females (%) | Mean tumor diameter in cm (range) | Mean tumor volume in cm³ (range) | SOES |
|---|---|---|---|---|---|---|---|---|---|
| Arai et al (2000)[26] | Tokyo, Japan | TCA | NA | 21 | 49 | 9 (43%) | NA | NA | 1 |
| Ciric and Rosenblatt (2001)[6] | NA | TCA | NA | 24 | 40 | 18 (75%) | NA | NA | 2 |
| Ohta et al (2001)[32] | Kobe city, Japan | TCA | 1980–2000 | 33 | 46.7 (15–69) | 29 (88%) | NA | NA | 2 |
| Zevgaridis et al (2001)[16] | Munich, Germany | TCA | 1990–1996 | 34 | 54.9 (38–80) | 27 (79%) | 2.8 (1.5–6) | NA | 2 |
| Fahlbusch and Scott (2002)[13] | Erlangen, Germany | TCA | 1983–1998 | 47 | 54.9 (28–74) | 39 (83%) | NA | NA | 2 |
| Goel et al (2002)[7] | Bombay, India | TCA | 1991–2001 | 70 | NA | 42 (60%) | NA | NA | 3 |
| Jallo and Benjamin (2002)[14] | New york, USA | TCA | 1983–2001 | 23 | 57.7 (4–73) | 15 (65%) | 3.3 (2–5) | 23.4 (8–60) | 1 |
| Chi and McDermott (2003)[5] | California, USA | TCA | 1992–2002 | 21 | 52.3 | 7 933%) | NA | NA | 2 |
| Schick and Hassler (2005)[15] | Duisburg, Germany | TCA | 1991–2002 | 53 | 53 (27–78) | 13 (25%) | 1–5 | NA | 1 |
| Pamir et al (2005)[29] | Istanbul, Turkey | TCA | 1987–2004 | 42 | 24–79 | 28 (67%) | NA | 7.5–21 | 1 |
| Mathiesen (2005)[33] | Stockholm, Sweden | TCA | NA | 29 | 58.3 | 23 (79%) | 2.3 | NA | 1 |
| Park et al (2006)[18] | Seoul, Korea | TCA | NA | 30 | 45 | 24 (80%) | 2.6 (1.6–6.3) | 12.4 (2.3–125.6) | 2 |
| Bassiouni et al (2006)[23] | Essen, Germany | TCA | 1990–2003 | 62 | 53 (29–81) | 46 (73%) | 3.4 (2–6) | NA | 1 |
| Nakamura et al (2006)[25] | Hanover, Germany | TCA | 1978–2002 | 72 | 54.3 (30–86) | 54 (75%) | 2.8 | NA | 1 |
| Otani et al (2006)[36] | Zurich, Switzerland | TCA | NA | 32 | 53.5 | 21 (66%) | 2.3 | NA | 2 |
| Kitano et al (2007)[21] | Osaka, Japan | TCA | 1994–2006 | 12 | 61.4 | 10 (83%) | NA | NA | 3 |
| Li X et al (2007)[35] | Jinan, China | TCA | 1989–2003 | 43 | 53.8 (24–68) | 31 (72%) | 1.8–5.4 | NA | 1 |
| De Divitiis et al (2008)[19] | Naples, Italy | TCA | 1983–2006 | 44 | NA | NA | NA | NA | 4 |
| Kim et al (2008)[27] | Gwangju, Korea | TCA | 1998–2006 | 27 | 53.8 (36–73) | 22 (80%) | 3 | NA | 2 |
| Mehrazin and Mirfalah. (2008)[38] | Tehran, Iran | TCA | 1997–2006 | 45 | 45.7 (22–75) | 35 (78%) | 2.6 (1.4–5.2) | NA | 1 |
| Nozaki et al (2008)[31] | Kyoto, Japan | TCA | 1999–2007 | 22 | 52.9 (27–73) | 18 (81%) | 2.3 (1.5–3.5) | NA | 2 |
| Fatemi et al (2009)[20] | California, USA | TCA | 2000–2008 | 9 | 49 (37–57) | 6 (73%) | 3.3 (2.2–5.5) | NA | 4 |
| Ganna et al (2009)[8] | Toronto, Canada | TCA | 2000–2007 | 24 | 53.8 | 20 (83%) | 2.6 | NA | 1 |
| Sade and Lee (2009)[30] | Ohio, USA | TCA | 1994–2006 | 31 | NA | NA | 2.3 (1.1–3.8) | NA | 3 |
| Galal et al (2010)[9] | Cairo, Egypt | TCA | 2000–2006 | 21 | 43 (27–65) | 14 (67%) | NA | NA | 1 |
| Landeiro et al (2010)[28] | Rio de Janeiro RJ, Brazil | TCA | 1997–2008 | 23 | 56.2 (38–77) | 15 (65%) | NA | NA | 1 |
| Palani et al (2012)[34] | Hyderabad, India | TCA | 2004–2011 | 41 | NA | 26 (63%) | NA | NA | 4 |
| Jang et al (2012)[37] | Gwangju, Korea | TCA | 2005–2011 | 24 | 49.5 (25–70) | 19 (79%) | 2 (0.7–3.3) | NA | 1 |
| Nanda et al (2013)[11] | Louisiana, USA | TCA | 1990–2013 | 30 | NA | NA | NA | NA | 4 |

(Continued)

**Table 2**  (*Continued*)

| Author/year | Study location | Surgery | Year of surgery | Total no. of cases | Mean age in years (range) | No. of females (%) | Mean tumor diameter in cm (range) | Mean tumor volume in cm$^3$ (range) | SOES |
|---|---|---|---|---|---|---|---|---|---|
| Lu Z et al (2012)[40] | Henan, China | TCA | 2005–2009 | 29 | 47 (25–69) | 19 (66%) | NA | NA | 3 |
| Soel HJ et al (2013)[39] | Seoul, Korea | TCA | 1994–2001 | 86 | 49 (24–75) | 66 (76%) | 2.4 (1–5.9) | 7.3 (1.1–64.1) | 1 |
| Yi et al (2014)[24] | Guangzhou, China | TCA | 2000–2008 | 106 | 48.5 (20–78) | 74 (70%) | 2.9 (0.8–4.9) | NA | 1 |
| Couldwell et al (2004)[52] | Salt Lake city, Utah | ETSA* | 1982–2003 | 11 | NA | NA | NA | NA | 4 |
| Kitano et al (2007)[21] | Osaka, Japan | ETSA | 1994–2006 | 16 | 53.8 | 14 (87%) | NA | NA | 3 |
| Laufer et al (2007)[47] | New York, USA | ETSA | NA | 5 | 55.6 (4–73) | NA | 2.6 (1.2–3.7) | NA | 4 |
| De Divitiis et al (2008)[19] | Naples, Italy | ETSA | 2000–2007 | 7 | 58.7 (47–80) | 4 (57%) | 2.5 (1.3–3.2) | 15.3 (3.2–24.1) | 4 |
| Gardner et al (2008)[48] | Pennsylvania, USA | ETSA | 2002–2005 | 13 | 52.2 (39–72) | 12 (92%) | NA | 7.5 (2.1–16.2) | 2 |
| Fatemi et al (2009)[20] | California, USA | ETSA[a] | 2000–2008 | 14 | 51 (31–77) | 10 (71%) | 2.5 (1.5–5.5) | NA | 2 |
| Wang et al (2010)[51] | Wuxi, China | ETSA | 2002–2007 | 12 | 56.7 (26–67) | 8 (67%) | 3.1 (2.5–4) | 15.4 (8.1–26) | 1 |
| Van Gompel et al (2011)[22] | Bologna, Italy | ETSA | 2003–2010 | 8 | 31–37 | NA | NA | NA | 4 |
| Ceylan et al (2011)[41] | Kocaeli, Turkey | ETSA | 2007–2010 | 9 | 52 (32–78) | 7 (78%) | 2.8 (1.6–4.5) | NA | 4 |
| Ogawa and Tominaga (2012)[45] | Sendai, Japan | ETSA | 2006–2011 | 19 | 58.9 (43–79) | 14 (74%) | 2 (0.9–2.9) | NA | 1 |
| Choudhury et al (2012)[42] | Dhaka, Bangladesh | ETSA | NA | 6 | 39.5 (29–52) | 4 (67%) | 3.5 (2–4) | NA | 4 |
| Bohman et al (2012)[50] | Philadelphia, USA | ETSA | NA | 5 | 53.2 (25–77) | 3 (60%) | 1.4–3 | NA | 4 |
| Attia et al (2012)[49] | NA | ETSA | NA | 6 | 56.5 (31–74) | 6 (100%) | 1–4 | NA | 4 |
| Gadgil et al (2013)[43] | Texas, USA | ETSA | 2009–2011 | 5 | 51 (31–66) | 3 (60%) | 2 (0.9–2.5) | 6.3 (2.3–11.9) | 4 |
| Khan et al (2014)[46] | Toronto, Canada | ETSA | 2006–2013 | 17 | 63.8 (37–86) | 13 (76%) | 2.3 91–3.3) | 10.1 (0.72–29) | 1 |
| Koutourousiou et al (2014)[44] | Pennsylvania, USA | ETSA | 2002–2011 | 75 | 57.3 (36–88) | NA | 0.5–5.2 | NA | 1 |

Abbreviations: ETSA, endoscopic transsphenoidal approach; SOES, strength of evidence score; TCA, transcranial approach.
[a]Endoscopic assisted microscopic transspheniodal approach.
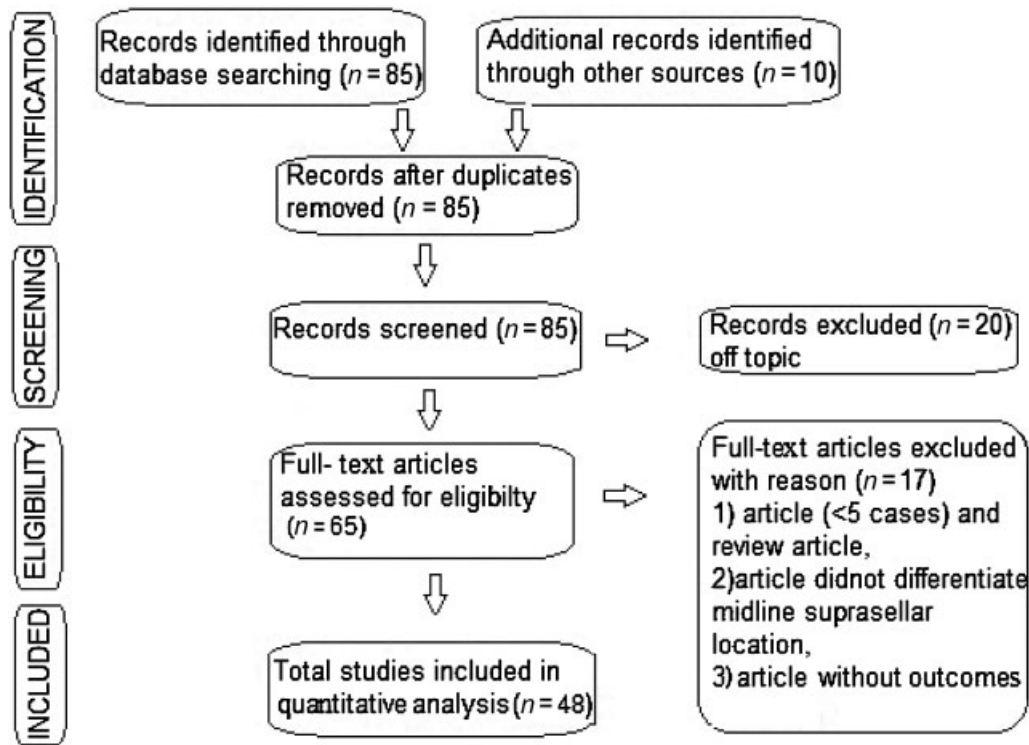
**Fig. 1** Flow diagram showing systemic analysis process (PRISMA flow diagram).

### Overcoming Bias

Only disaggregated data were included for analysis of predictive factors. An assessment of bias was made only on the outcome measures but not on individual studies because only case series and case reports were included in this study. Publication bias was assessed by using funnel plots on natural logarithmic scale followed by Egger's linear regression. The study design is presented in a flow diagram (►**Fig. 1**).

### Statistical Analysis

Statistical analysis was done by using SPSS software (version 17.0; Chicago, Illinois, United States) and Stata (version 11.0; college station, Texas, United States). Meta-analysis on calculated pooled proportion of individual outcomes for TCA and ETSA groups was independently performed. The disaggregated individual patient data from studies were summarized for the purpose of statistical analysis. Results were designated as proportions (%) and 95% confidence intervals (CI) were resolved using the exact binomial method. Heterogeneity was estimated using Cochran Q statistic, and random effect models were used to correlate the heterogeneity between proportions as previously described[53–56].Each individual study was weighted by using the inverse variance method at 95% CIs and each pooled effect size proportion was estimated by using inverse Zr transformation of the proportion generated from random effects model.[53–56]Between the groups, hypothesis testing was performed on calculated 95% CIs of the pooled proportions. Odds ratio (OR) was calculated by dividing the pooled TCA proportion by the pooled ETSA proportion for the specific outcome of interest.

### Results

#### Preoperative Assessments

Out of a total of 1,466 patients who were admitted for MSM surgery involving TCA and ETSA, females were in the majority for both approaches (►**Table 3**). There was a significant difference between the two approaches with regard to mean patient age, visual impairment, mean length of follow-up, and headache, but not tumor size and volume (►**Table 3**).

#### Postoperative Assessment of Outcome Measures

For both approaches, worsening of visual impairment, visual improvement, and GTR numerically differed; however, the differences were statistically insignificant except in the case of CSF leakage (►**Table 4**, ►**Fig. 2**, **3** and **4**).Comparing various overall perioperative complications with respect to the two approaches, it was found that both procedures had association with some complications (seizure, CSF leakage, hemorrhage, and mortality), while there was no association for others (visual worse, infections, endocrinopathy, and anosmia) (►**Fig. 6**). TCA was associated with decreased CSF leakage but increased recurrence rate, while ETSA showed decreased recurrence rate but increased CSF leakage, and the differences between the two approaches were statistically significant (►**Table 4**).

#### Publication Bias for Pooled Proportion

Finally, we investigated publication bias of case series for significant and nonsignificant pooled proportions with Begg's funnel plot, and it showed similar asymmetry. Only

**Table 3** Comparison of clinical characteristics of patients who underwent TCA and ETSA for resection of midline suprasellar meningiomas, from studies in which patient data were reported in disaggregated form

| Preoperative variables | No. of studies | TCA | No. of studies | ETSA | p- Value |
|---|---|---|---|---|---|
| Age (y) | | | | | |
| <50 y (%) | 11 | 428(44) | 1 | 6(3) | 0.001 |
| >50 y (%) | 15 | 524(55) | 13 | 203(97) | |
| Sex | | | | | |
| Male (%) | 29 | 336(30) | 12 | 39(28) | 0.776 |
| Female (%) | 29 | 782(70) | 12 | 98(71) | |
| Presenting symptoms | | | | | |
| Headache (%) | 12 | 244(42) | 10 | 30(20) | 0.001 |
| Endocrine abnormalities (%) | 7 | 34(13) | 4 | 10(9) | 0.362 |
| Preoperative visual deficits (%) | 31 | 1,075(91) | 15 | 175(81) | 0.001 |
| Tumor characteristics | | | | | |
| Mean tumor diameter, cm (range) | 18 | 3(0.8–63) | 12 | 2.5(0.5–5.9) | 0.135 |
| Mean tumor volume, cm$^3$ (range) | 4 | 14.3(1.1–125.6) | 5 | 11(0.7–29) | 0.072 |
| Optic canal involvement (%) | 9 | 149(36) | 1 | 20(26) | 0.114 |
| Major vascular encasement (%) | 8 | 135(40) | 4 | 59(47) | 0.218 |
| Mean follow-up (mo, range) | 27 | 53(3–192) | 12 | 19(1–98) | 0.002 |
| Mean tumor volume, cm$^3$ (range) | 4 | 14.3(1.1–125.6) | 5 | 11(0.7–29) | 0.072 |

Abbreviations: ETSA, endoscopic transsphenoidal approach; TCA, transcranial approach.

Funnel plot with respect to CSF leakage is shown (►**Fig. 5**) and it was a nonsignificant plot ($p > 0.05$). From Egger's test performed on the publications used in this study, there was no bias with specific respect to visual improvement, GTR, and CSF leakage (►**Table 5**).

## Discussion

### Background
Complete removal of MSM via the TCA, first described by Stirling and Edin in 1897,[57] was performed by Cushing and Eisenhardt in

**Table 4** Comparison of surgical outcomes after resection of midline suprasellar meningioma (MSM) between TCA and ETSA groups

| Variables | Proportion | OR; 95% CI | p-value |
|---|---|---|---|
| GTR | | | |
| TCA | 0.80 | 1.3; 0.74–7.68 | 0.43 |
| ETSA | 0.83 | | |
| Visual improved | | | |
| TCA | 0.71 | 1.2; 0.25–8.92 | 0.26 |
| ETSA | 0.70 | | |
| CSF leak | | | |
| TCA | 0.08 | 2.5; 1.78–11.56 | 0.04 |
| ETSA | 0.17 | | |
| Visual worse | | | |
| TCA | 0.18 | 1.6;0.43–6.11 | 0.12 |
| ETSA | 0.15 | | |
| Tumor recurrence | | | |
| TCA | 0.07 | 1.8; 1.1–6.39 | 0.02 |
| ETSA | 0.05 | | |

Abbreviations: CI, confidence interval; CSF, cerebrospinal fluid; ETSA, endoscopic transsphenoidal approach; GTR, gross total resection; OR, odds ratio; TCA, transcranial approach.
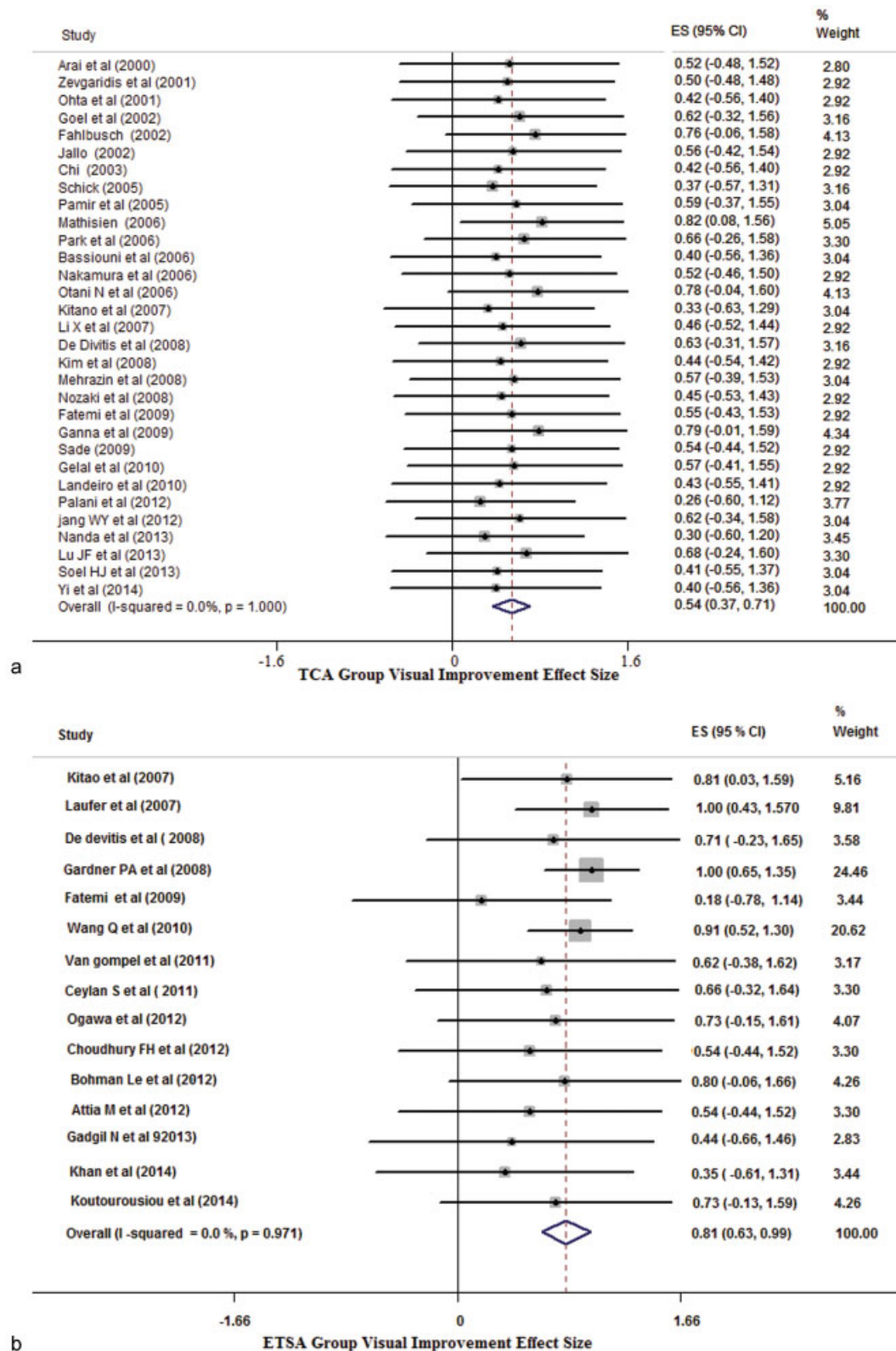
**Fig. 2** It demonstrates comparison between transcranial and endoscopic transsphenoidal approach with respect to postoperative visual improvement. Forest plot demonstrates the 95% confidence intervals and percentiles weights associated with the individual and combined study groups for (**a**) transcranial approach group and (**b**) endoscopic transsphenoidal approach group.
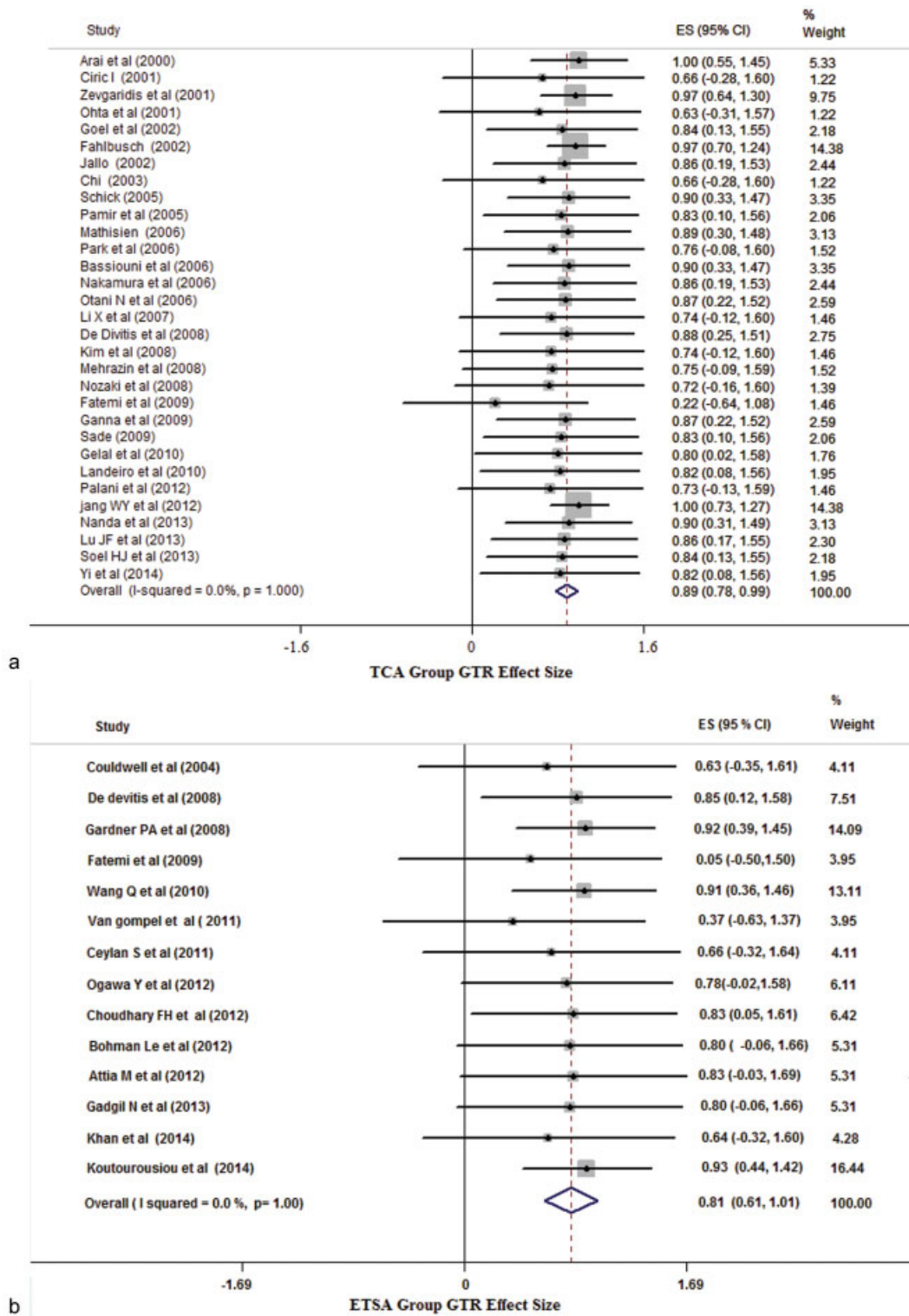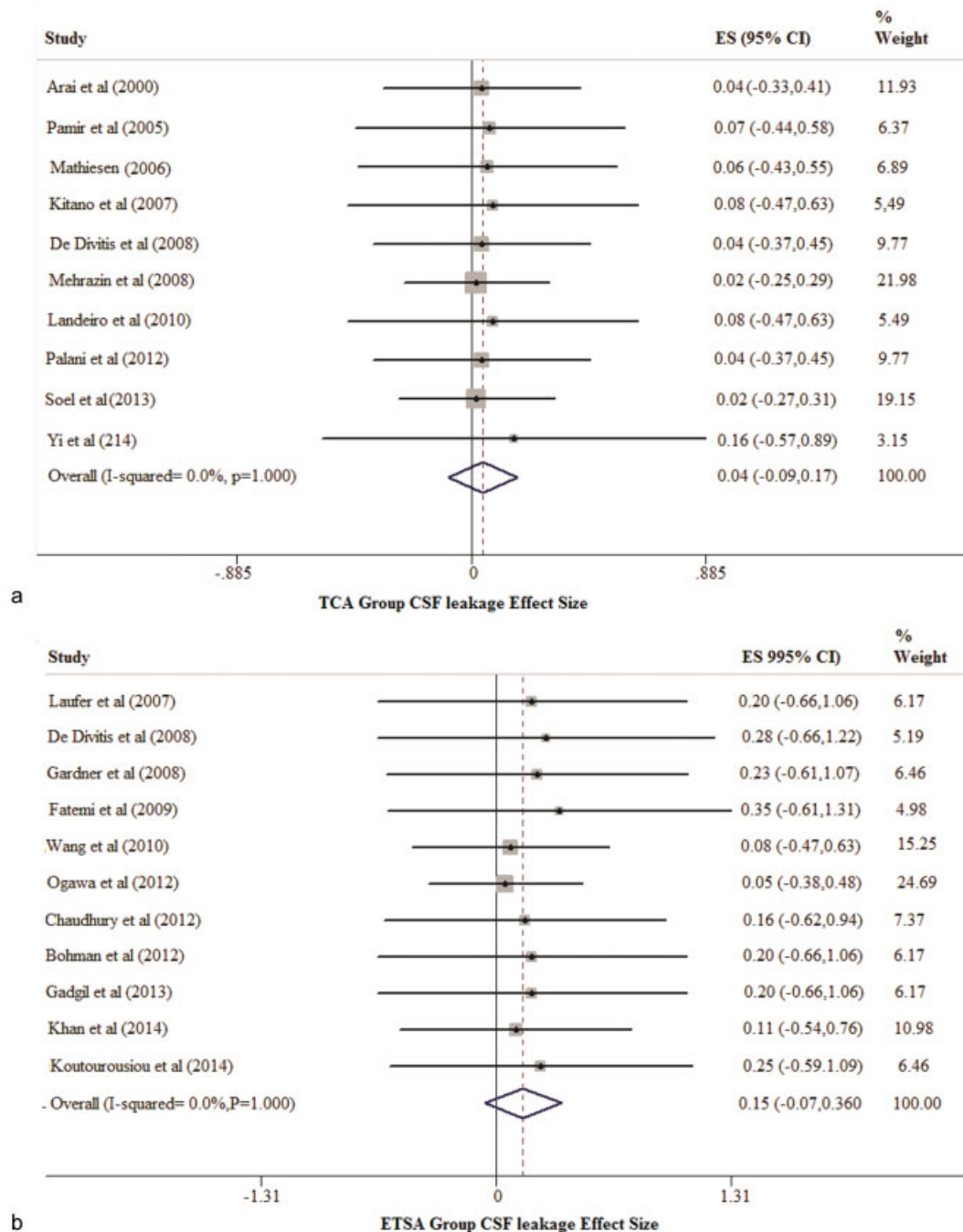
Fig. 3 It demonstrates comparison between transcranial and endoscopic transsphenoidal approach with respect to gross total resection. Forest plot demonstrates the 95% confidence intervals and percentiles weights associated with the individual and combined study groups for (a) transcranial approach group and (b) endoscopic transsphenoidal approach group.

1916.[58] Since then, MSMs have been removed by different transcranial approaches that include: frontolateral, frontotemporal/pterional, orbitopterional/orbitozygomatic, unilateral subfrontal, bilateral subfrontal, interhemispheric, supraorbital, and pterional.[7,13,14,25,30–33,59,60] With time, the

complications, risks, and associated morbidities with TCA gave rise to TSA that was devoid of the previous risks. TSA was introduced by Herman Schloffer, who in 1907 resected a pituitary tumor via TSA.[61] TSA was found to be effective and safer for suprasellar meningiomas that were predominantly

**Fig. 4** It demonstrates comparison between transcranial and endoscopic transsphenoidal approach with respect to cerebrospinal fluid leakage. Forest plot demonstrates the 95% confidence intervals and percentiles weights associated with the individual and combined study groups for (a) transcranial approach group and (b) endoscopic transsphenoidal approach group.

located in the midline[17,47,62–66] though its study-based advantages and disadvantages need affirmation.[13,25,52,67] Even though TSA has refined with evolution of microscope-based[52,68] or currently by endoscope-based techniques,[21,47,69–71] there still remains the most common problem of CSF leakage. Similarly, to limit this CSF leakage during ETSA, varieties of closure methods like: fat and fascial graft,[72] fat and synthetic dural substitute,[51] mixture (fascial graft, methacrylate, mucoperichondrium, and fibrin glue),[73] mixed (fascia lata and Nissel or DuraSeal),[47] or mixed (fascial graft and nasoseptal flap)[46] for dural reconstruction have been proposed. Among these closure methods, a study done by de Divitiis[19] has reported a higher (29%) rate of CSF leakage that specifically utilized a multilayer closure involving collagen matrix, dural substitute, a reabsorbable plate, and fibrin sealant. Various reconstruction techniques during the TCA have been suggested to prevent postoperative CSF leakage that occur mainly in the frontal sinus[74] and resultant meningitis, including the use of pericranial flap with or without adipose tissue being the most popular one.[6,75] Progressively, however, with the evolution of vascularized nasoseptal flap reconstruction technique, the CSF leakage rate has dramatically decreased to 16% with a p-value
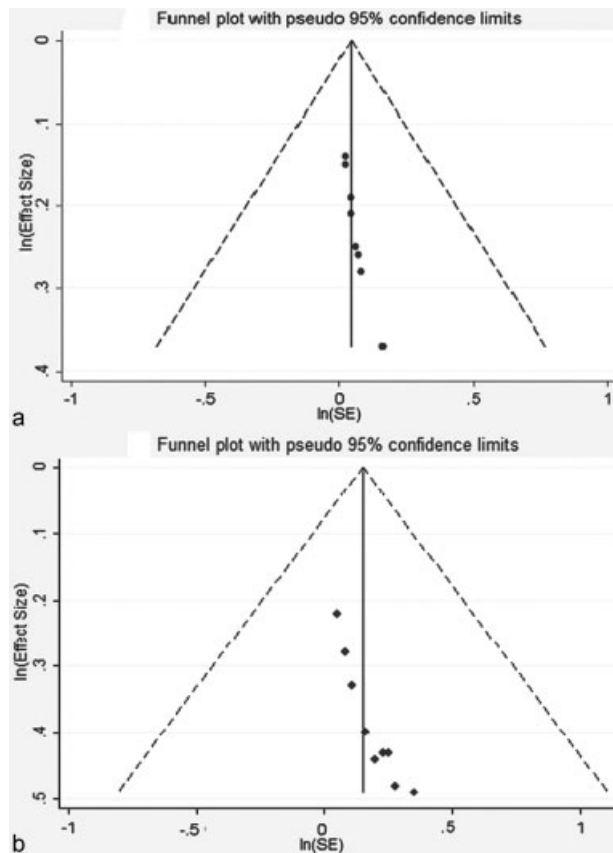
Fig. 5 Begg's funnel plot for publication bias in cerebrospinal fluid leak for both (a) transcranial approach and (b) endoscopic transsphenoidal approach. Points indicate the effect size (pointed as a proportion) included in meta-analysis plotted against the calculated standard error on a natural logarithm scale, dashed line represents 95% confidence interval,

approaching <0.0001.[76,77] Whatever the modification be made with procedures, reconstruction performed with a dural or institution of a newer vascularized nasoseptal sealing technique, higher rate of CSF leakage still persists with ETSA.

## Evolution of Microscopic and Endoscopic Transsphenoidal Approach

ETSA is an endoscopic-guided MSM removal procedure that delivers good illumination, wide panoramic view of the surgical target especially between the PS and clival recess.

Some of the studies performed on ETSA have reported complete resection of tumor in 88 % patients, with visual improvement in 87% and visual worsening in 6%[78] while Couldwell et al[52] have reported complete resection in 64% patients with tuberculum sellae meningioma and visual worsening in 9 % with microscope-based TSA. Similar results have also been documented by Fatemi et al with complete resection in 50% patients, near total resection in 21% patients, with visual improvement in 82% and visual worsening in 7%.[20] However, access through a small aperture of nasal speculum in the microscope-based TSA approach alone had drawbacks by the limited exposure of operative corridor, field of view of surgical target, and surgical freedom of instrument maneuverability. Moreover, studies performed by Kaptain et al, Dusick et al, Cook et al, and Couldwell et al comparing the superiority among these procedures, have revealed that rather than individual microscope-based TSA or ETSA, combination of both procedures were found to be the superior approach due to the wide degree of visual freedom it provided during exploration and removal of the tumor.[17,52,62,63]

## Procedures Related Advantages and Disadvantages of Transcranial Approach and Endoscopic Transsphenoidal Approach

Both of the procedures have their own advantages over each other but the specific choices in treatment of MSM have been on an ad hoc basis. The important advantages of the TCA have been: surgeon's familiarity with traditional approach, direct microscopic visualization of the tumor, early identification of adjacent neurovascular structure, early decompression of the optic nerve via anterior clinoidectomy, increased range of instrument maneuverability (surgical freedom), better control of vascular structures, and ability to address tumor that extends superiorly or laterally on the optic nerve.[72] TCA, however, has some disadvantages like: easily visible scar, longer recovery time, risk of injury to brain tissue caused by frontal lobe retraction, difficulty in removing tumors located medial to ipsilateral carotid artery/optic nerve,[19,72] and the incidences of increased blood losses. Similarly, ETSA has been superior at early devascularization of the main feeding arteries,[19] early decompression of the medial side of optic nerve by unflooring the optic canal,[21] visualizing the lower plane of the optic chiasma,[9,51,52,72] and providing better

**Table 5** Summary of results of publication bias

| Approaches | Variables | Publication bias (p-value) | | Number of studies |
|---|---|---|---|---|
| | | Begg's | Egger's | |
| TCA | Visual improvement | 0.07 | 0.12 | 31 |
| | Gross total resection | 0.23 | 0.27 | 31 |
| | CSF leak | 0.36 | 0.41 | 10 |
| ETSA | Visual improvement | 0.22 | 0.18 | 15 |
| | Gross total resection | $p = 0.59$ | $p = 0.45$ | 14 |
| | CSF leak | $p = 0.09$ | $p = 0.11$ | 12 |

Abbreviations: CSF, cerebrospinal fluid; ETSA, endoscopic transsphenoidal approach; TCA, transcranial approach.
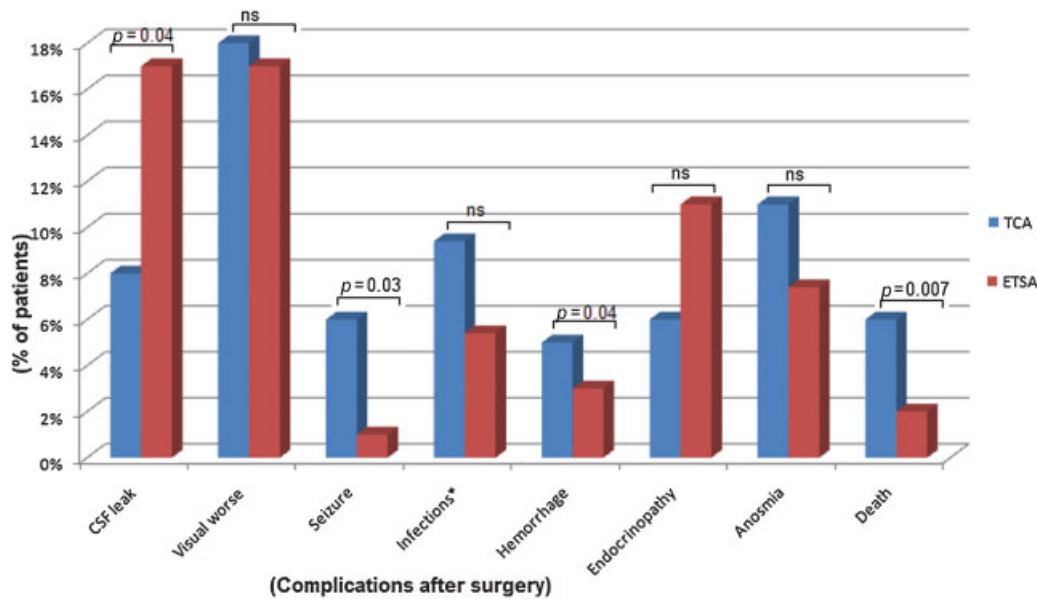
**Fig. 6** Perioperative complications following transcranial and endoscopic transsphenoidal approach for midline suprasellar meningioma resection.

cosmetic results.[51] This approach also shortens the recovery time, lessens injury to brain parenchyma (no brain retraction),[19] provides clear vision between the internal carotid artery (ICA) to ICA and easy removal of sellar extension tumors. Moreover, it has also been the choice of surgery in elderly patients or patients with major comorbidities that cannot stand surgery.[21,52] However, ETSA has been limited in number of cases due to increased risk of CSF leakage/CSF fistulae[19,52] and inadequate removal due to the nature of tumor (hard/calcified/large/above optic nerve/ more laterally located).[19]

### Surgical Outcomes

The reports of the present study relate favorably with those of other studies.[19,20,78,79] For example, Komotar et al observed significantly higher rate of GTR in endoscopic group compared with transcranial group (92.8 vs 63.2%; $p < 0.001$).[79] Removal of the tumor as much as possible is the ultimate goal of resection in neurosurgery. Nonetheless, several studies have highlighted the fact that complete resection at the cost of visual deterioration or hypothalamic dysfunction should not be attempted. With the advent of modern microsurgery, the amount of GTR rate has leaped from 35 to 76% (macrosurgical era) to 58 to 100% (of the microsurgical era).[25] Resection of MSM is a complex procedure and depends on various factors like size of meningioma, arterial encasement, peritumoral edema, and approaches followed.[34] Whatever the influential factor may be, the extent of resection is paramount in predicting subsequent recurrence. Studies conducted earlier have reported the yield of GTR during TCA to be 70 to 100% while that with ETSA to be between 50 to 84%.[20,63] Contrarily, studies conducted by de Divitiis et al[19] have revealed 83.3% GTR during TCA while 86.4% GTR yield during ETSA. Our findings too followed the latter pattern with 80% GTR during TCA and 83% GTR during ETSA, with no statistical association ($p = 0.43$).

One of the undesired results of MSM surgery is tumor recurrence which is influenced by varieties of factors. As outlined by Fahlbusch and Schott,[13] these factors can be: 1) extent of tumor resection, 2) histological grading of the tumor, 3) length of follow-up period, and 4) mode and quality of assessment of tumor recurrence. TSA approach being less invasive with a shorter hospital stay, the compliance to long-term follow-up becomes questionable. Most of the previously conducted ETSA studies have had 6 to 24 months of follow-ups (mean, $21 \pm 18$ months)[51] while the mean follow-up duration for TCA was 51.8 months (0.8–112 months).[79] Recurrence rate for MSM ranges from 5% to $> 30$ % and the rate increases with longer follow-ups.[1–3,10,12,80] Our observations, as shown in ►**Table 3**, too shared the same fact as seen by lack of 100% follow-up rates with both the procedures, (TCA, 73.3% vs ETSA, 79%). Moreover, the length of mean follow-up period for TCA was longer as compared with ETSA (53 vs 19 months) and the $p$-value approaching 0.002. As a result, the recurrence rate with TCA was higher as compared with ETSA (7 vs 5%; $p = 0.02$). Meningiomas, although histologically benign, can recur and progress over time, so longer follow-up is necessary to evaluate the long-term outcome.

As mentioned earlier, good visual outcome is the target of a successful MSM surgery. In relation to the surgical approach undertaken, recent meta-analysis have demonstrated more visual improvements with ETSA (75%) as compared with TCA (58.4%), although the observations did not have statistical significance.[19] Our studies also demonstrated almost similar rate of visual improvement with no statistically significant difference (TCA vs ETSA, 71 vs 70%; $p = 0.26$)), as depicted in ►**Table 4**. Moreover, some series have identified ETSA to deliver higher visual functional improvement in comparison to TCA.[22,49,69,79,81] Our observations, however, also demonstrated higher rate of visual worsening with TCA

than with ETSA and no statistical association (18 vs 15%; $p = 0.12$). This lower rate of visual worsening encountered with the ETSA approach was attributed to minimal manipulation of compromised ischemic optic apparatus, adequate and early visualization of the subchiasmatic blood vessels, and precision and safer handling of the optic apparatus.[51]

### Operative Complications

On the other hand, we observed that both TCA and ETSA did not differ significantly in visual improvement and GTR but postoperative complications, specifically, seizure and hemorrhage was significantly predominant in TCA as compared with ETSA.[19,78] Some series reported that surgical morbidities such as seizure and hemorrhage were lower in patients treated with ETSA as compared with TCA. Symon and Rosenstein also reported that new onset seizure was a commonly occurring complication of MSM surgery being as high as in 10.9% of cases during TCA.[82] Our study also revealed cases of new onset seizure and the prevalence being more (6%) with TCA than with ETSA (1%). Similarly, intracerebral hemorrhage was found to be more with TCA than ETSA (5 vs 3%). Observation of low cases of seizure and hemorrhage in ETSA in comparison to TCA is expected because in TCA, more or less frontal lobe retraction needs to be done which may cause rupture of small feeding blood vessels and injury to brain parenchyma causing seizure. But ETSA has been superior to TCA in the field of early devascularization of main feeding vessels and no brain retraction.[19] Theoretically, postoperative CSF leakage is a potential complication of approaches and occurs via the frontal sinus during TCA. But in practice and in numerous researches namely, Komotar et al[79] (21.3 vs 4.3%; $p < 0.001$), ETSA is found to be associated with higher rates of CSF leakage than with the TCA.[19,20,63,83] Our study has also shown that postoperative CSF leakage occurs more with ETSA than with TCA (17 vs 8%; $p = 0.04$) (►**Table 4**).

Finally, we report that TCA and ETSA surgical approaches for MSM removal do not display complete superiority over each other when assessed on the basis of postoperative outcome measures. This was apparent since TCA and ETSA displayed poor outcomes with regard to recurrence rates and CSF leakage respectively, coincidentally, two of the commonly used postoperation determinants of improvement. Generally, it was observed that both TCA and ETSA did not improve worsening of visual function, visual improvement, and GTR. However, reduced CSF leakage and increased recurrence rate was associated with TCA, while reduced recurrent rate and increased CSF leakage was attributable to ETSA. The poor recurrence rate associated with TCA may be linked to the long follow-up period, while the comparatively reduced recurrence rate in ETSA cohorts may be accounted for by the short follow-up period. It was apparent that patients who underwent MSM removal by both TCA and ETSA have almost similar preoperative clinical characteristics, an observation which strengthens the comparability of the two cohorts. The results of this review are not much different from recent studies, which have shown that none of the surgical approaches could

be seen as an end in itself since both have advantages and disadvantages, thus the choice of TCA or ETSA may be determined by tumor characteristics, patient-specific clinical presentations, risk/benefits, and prioritization of clinical objectives.

## Limitations

This study, among other factors, may be limited by case heterogeneity, methodological heterogeneity which cannot be cured completely by statistical method, because the study is retrospective in nature. For instance, length of follow-up and tumor characteristics for both cohorts in some cases differed.

## Conclusions

Put together, the choice of TCA or ETSA for surgical removal of MSMs may depend on many factors including tumor characteristics, patient-specific clinical presentations, risk/ benefit assessment, and the clinical objective. Ideally, a surgical approach that can maximize the advantages of both TCA and ETSA while at the same time minimize the risks associated with these approaches must be sought.

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