Surgical management of colloid cysts of the third ventricle: a single-institution comparison of endoscopic and microsurgical resection

Thomas L. Beaumont, MD, PhD, David D. Limbrick Jr., MD, PhD, Bhuvic Patel, MD, Michael R. Chicoine, MD, Keith M. Rich, MD, and Ralph G. Dacey Jr., MD

Department of Neurological Surgery, Washington University School of Medicine, St. Louis, Missouri

OBJECTIVE Colloid cysts of the third ventricle are histologically benign lesions that can cause obstructive hydrocephalus and death. Historically, colloid cysts have been removed by open microsurgical approaches. More recently, minimally invasive endoscopic and port-based techniques have offered decreased complications and length of stay, with improved patient satisfaction.

METHODS A single-center retrospective analysis of patients with colloid cysts who underwent surgery at a large tertiary care hospital was performed. The cohort was assessed based on the surgical approach, comparing endoscopic resection to open microsurgical resection. The primary endpoint was rate of perioperative complications. Univariate analysis was used to assess several procedure-related variables and the cost of treatment. Multivariate analysis was used to assess predictors of perioperative complications. Total inpatient cost for each case was extracted from the health system financial database.

RESULTS The study included 78 patients with colloid cysts who underwent resection either via an endoscopic approach (n = 33) or through a craniotomy (n = 45) with an interhemispheric-transcallosal or transcortical-transventricular approach. Nearly all patients were symptomatic, and half had obstructive hydrocephalus. Endoscopic resection was associated with reduced operative time (3.2 vs 4.9 hours, p < 0.001); lower complication rate (6.1% vs 33.1%, p = 0.009); reduced length of stay (4.1 vs 8.9 days, p < 0.001); and improved discharge to home (100% vs 75.6%, p = 0.008) compared to microsurgical resection. Coagulated residual cyst wall remnants were more common after endoscopic resection (63.6% vs 19.0%, p < 0.001) although this was not associated with a significantly increased rate of reoperation for recurrence. The mean follow-up was longer in the microsurgical resection group (3.1 vs 4.9 years, p = 0.016). The total inpatient cost of endoscopic resection was, on average, one-half (47%) that of microsurgical resection. When complications were encountered, the total inpatient cost of microsurgical resection was 4 times greater than that of endoscopic resection where no major complications were observed. The increased cost-effectiveness of endoscopic resection remained during reoperation.

CONCLUSIONS Endoscopic resection of colloid cysts of the third ventricle offers a significant reduction in perioperative complications when compared to microsurgical resection. Endoscopic resection optimizes nearly all procedure-related variables compared to microsurgical resection, and reduces total inpatient cost by > 50%. However, endoscopic resection is associated with a significantly increased likelihood of residual coagulated cyst wall remnants that could increase the rate of reoperation for recurrence. Taken together, endoscopic resection represents a safe and effective minimally invasive approach for removal of colloid cysts.

https://thejns.org/doi/abs/10.3171/2021.11.JNS211317

KEYWORDS colloid cyst; hydrocephalus; endoscopic; third ventricle; neuroendoscopy; oncology
to which they are commonly adherent. Historically, they have been removed with transcranial microsurgery via an interhemispheric-transcallosal (IHTC) or transcortical-transventricular (TCTV) approach. The former has been favored due to concern for an increased likelihood of seizures following transcortical approaches, although reported data are somewhat anecdotal.\(^5\)\(^6\)\(^7\) Open microsurgical approaches have a relatively high rate of complications in reported series, ranging from 3.5% to 33%, with an average rate of at least 20%.\(^8\)\(^9\)\(^10\) Over the past 2 decades, neuroendoscopic techniques have offered increasingly favorable results with significantly decreased complication rates ranging from 3% to 10%, along with optimal procedure-related variables and improved patient satisfaction.\(^10\)\(^11\)\(^12\)\(^13\)

Early case series comparing endoscopic resection to microsurgical resection consistently demonstrated decreased operative time and decreased perioperative complications including the elimination of perioperative death, and reduced length of stay (LOS).\(^5\)\(^6\)\(^14\)\(^15\) However, these studies also demonstrated an increased rate of residual cyst wall remnants and cyst recurrence following endoscopic resection, which was confirmed in several subsequent case series.\(^15\)\(^16\)\(^17\)\(^18\) As the endoscopic technique has continued to evolve, more recent series describe rates of gross-total resection and recurrence similar to that achieved by microsurgical techniques.\(^13\)\(^19\) Nonetheless, it remains unclear how the presence of coagulated cyst wall remnants after endoscopic resection is associated with radiographic recurrence and the need for reoperation, because the data have been somewhat inconsistent.\(^20\)\(^21\)\(^22\)

Here we report a retrospective cohort of patients with colloid cysts treated with either single burr hole endoscopic resection or open microsurgical resection at a large tertiary care hospital. The primary endpoint was the rate of complications. Specific emphasis was placed on comparing procedure-related variables, LOS, disposition, rate of residual cyst wall remnants, and rate of cyst recurrence, as well as total inpatient costs.

**Methods**

**Patient Population**

We performed a retrospective review of all patients with colloid cysts of the third ventricle who underwent surgery at a large academic medical center between 1998 and 2018. The study was performed with the approval of the institutional review board in accordance with the Health Insurance Portability and Accountability Act (HIPAA). Cases were identified using an institutional radiology database and the neurosurgery coding database. In the former, initial searches using “colloid cyst” were performed and studies pertaining to regions other than the brain were discarded. The coding database was queried for the ICD-9 diagnosis codes 225 and 331.4, indicating “benign neoplasm of the brain” and “obstructive hydrocephalus,” respectively. The selected records were queried for “colloid cyst” and subsequently combined with the imaging database search results. A final list of nonredundant cases was then generated. Cases were excluded if detailed clinical information was unavailable (\(n = 1\)), or if the patient underwent shunting only (\(n = 3\)). One additional patient was excluded who had undergone bilateral shunting at an outside institution, and had chronic wound dehiscence, meningitis, and vasospasm. This patient was transferred to our institution, where the shunts were externalized and he was treated with antibiotics as well as hypervolemic, hyperdynamic therapy. The patient ultimately underwent endoscopic resection along with endoscopic third ventriculostomy. Patients were followed in clinic by the attending neurosurgeon with surveillance neuroimaging at 3 months, 6 months, and 1 year postoperatively, with annual imaging thereafter. All study participants including patients lost to follow-up were queried in the National Death Index to identify unreported or unexplained deaths within the cohort.

**Study Parameters**

Univariate analysis of the endoscopic resection group versus the microsurgical resection group evaluated several demographic and clinical variables including age at presentation, sex, cyst diameter, cyst volume \((4/3 \pi r_1^2 r_2)\), symptomatic clinical status, Evans ratio, presentation with hydrocephalus, and Colloid Cyst Risk Score (CCRS) \(\geq 4\). Hydrocephalus was defined as ventriculomegaly on neuroimaging with Evans ratio > 0.30 and the presence of \(\geq 1\) symptom of elevated intracranial pressure including the following: headache, nausea with or without emesis, blurred vision or diplopia, dizziness or ataxic gait, cognitive decline, syncope, or bradycardia. Acute hydrocephalus was defined as hydrocephalus with symptom onset or acute progression from baseline within 24 hours of presentation.\(^23\) Key procedure-related variables, the occurrence of complications, and disposition were also assessed with univariate analysis and the relative risk was calculated. Recorded complications included postoperative seizures, venous thromboembolism (VTE), venous infarction or intracerebral hemorrhage, intraventricular hemorrhage, infection, and persistent memory/neurological deficits at 1-year clinical follow-up. Neuropsychological testing was reserved for patients with memory deficits noted at follow-up, and was not routinely performed. All complications were considered individually and were also combined into a single dichotomous variable. Operative time was taken as the number of minutes from anesthesia induction to removal of the sterile drapes, to account for differences in patient positioning and setup. Any case in which residual cyst wall was noted at the conclusion of surgery, even if the remnant was minuscule and thoroughly coagulated, was included as “residual cyst wall present.” Postoperative LOS was calculated from the day of surgery to the day of discharge from hospital. The reoperation rate was further subdivided, because some patients with complications required a return to the operating room that was unrelated to cyst recurrence. Multivariate analysis was performed to control for factors potentially contributing to the occurrence of complications and to identify independent predictors. Total inpatient cost for each case was extracted from the health system billing database, adjusted based on the consumer price index, and referred to herein as “total inpatient cost.”

**Operative Technique**

Patients underwent colloid cyst removal by either open...
microsurgical resection with standard IHTC or TCTV technique, or by single burr hole endoscopic resection (Fig. 1). Approach selection was based on the preference of the treating neurosurgeon.

For the endoscopic technique, patients were positioned supine with the head immobilized in Mayfield pins. A burr hole was planned approximately 4 cm lateral to midline and 5 cm anterior to the coronal suture (approximately 8 cm posterior to the nasion) using image guidance (Fig. 1). The final location was optimized to provide maximal access below the fornix while avoiding the caudate nucleus. A 2.5-cm coronal incision was placed behind the hairline. Following burr hole placement, a 19-Fr peel-away introducer (Aesculap) was passed into the ventricle under image guidance. A 30° ventriculoscope (MINOP; Aesculap) was used for all endoscopic procedures along with constant warm saline irrigation. The cyst wall and overlying choroid plexus were coagulated using a ball-tip monopolar electrode (Karl Storz) and the cyst was opened sharply. Cysts containing viscous fluid were evacuated with suction, and those with mineralized contents were evacuated with a combination of grasping forceps and a suction-morcellation device (Myriad; Nico Corp.). Following internal decompression, any cyst-associated vessels were coagulated, the cyst margins were developed with blunt and sharp dissection, and the cyst wall was resected using the Myriad. Any residual cyst wall that remained adherent to the fornix, tela choroidea, or internal cerebral veins was carefully coagulated. In rare instances the cyst wall could be circumferentially freed, allowing en bloc removal. Septostomy was performed with a monopolar electrode followed by a balloon dilator (Neuro-Balloon; Integra NeuroSciences). Historically an external ventricular drain (EVD) was routinely left in place at the end of the procedure. However, over time, EVD placement was reserved for cases in which bleeding was encountered.

Statistical Analysis

All statistical analysis was performed using IBM SPSS version 27 (IBM Corp.). For continuous variables, Levene’s test for equality of variances was performed, followed by the Student t-test. Continuous variables are expressed as the mean ± SD. Values of p < 0.05 were considered statistically significant. All statistical tests were 2-tailed unless specifically stated otherwise. Categorical variables were explored with the chi-square and Fisher exact tests. Relative risk was calculated for dichotomous variables. Logistic regression was used to assess variables associated with complications, and standardized residuals were evaluated for normalcy. Variables for which maximum likelihood could not be estimated due to limited variance (Evans ratio, acute hydrocephalus) were excluded from the model. The sample size required to achieve 80% power was estimated a priori by using a Pearson chi-square test with an estimated effect size of 0.3, $\alpha = 0.05$. Post hoc power analysis indicated 76.3% power for exact tests related to the primary endpoint with pooled standard deviation.

Results

Patient Characteristics

The retrospective cohort was composed of 78 cases of colloid cyst of the third ventricle, the majority of which were symptomatic at the time of presentation (93.6%, n = 73). The most common presenting complaints included sequelae of CSF obstruction such as headache, nausea/vomiting, blurred vision or diplopia, dizziness or ataxic gait, and syncope, consistent with prior reports.2,5,23–25 Hydrocephalus was present in 47.4% of patients, 5 of whom (6.4% overall) presented acutely. Patients were subgrouped based on surgical approach: single burr hole endoscopic resection (n = 33) (Fig. 1) and microsurgical resection (n = 45). The microsurgical subgroup included either the TCTV (n = 10) and more commonly the IHTC (n = 35) approach. There were no significant differences in age, sex, mean axial cyst diameter, cyst volume, or presentation with obstructive hydrocephalus and preoperative EVD placement between the endoscopic resection and microsurgical resection subgroups (Table 1). All patients who presented with acute hydrocephalus (n = 5) were treated microsurgically. Even so, > 90% of patients in both groups had a CCRS ≥ 4 at the time of surgery, and there was no significant difference in the proportion of patients with a CCRS of 5 (53.3% vs 62.5%, p = 0.384).

Procedural Comparison

The endoscopic resection subgroup (n = 33) was compared to the microsurgical resection subgroup (n = 45). The former procedures were performed by 1 of 2 primary endoscopic surgeons, with the senior neuroendoscopist involved in 31/33 (94%) of endoscopic resection cases, whereas the latter were performed by 12 different primary surgeons. Endoscopic resection of colloid cysts significantly optimized nearly all procedure-related vari-
ables compared to microsurgery, with the single exception being the presence of residual cyst wall remnants noted at the conclusion of surgery (63.6% vs 19.0%, p < 0.001, RR 2.7) (Table 2). Operative time was reduced by 42% (3.0 vs 5.2 hours, p < 0.001) in the endoscopic group compared to the microsurgical group. There was no difference in the rate of postoperative EVD placement. Of note, the use of temporary postoperative CSF drainage significantly decreased in the endoscopic group over time. If the endoscopic resection subgroup was evenly divided over the study interval, an EVD was left in place after surgery in 44% of the first half of the cases and only 13% of the second half (p = 0.023). Septostomy was performed more frequently in the endoscopic group (87.9% vs 33.3%, p < 0.001) and is now a standard part of the procedure at our institution. Endoscopic resection was associated with a 54% reduction in LOS (4.1 ± 1.9 vs 8.9 ± 7.5 days, p < 0.001) and all patients were discharged home, compared to 24% of patients in the microsurgical resection group who were discharged to a rehabilitation facility. There were no procedure-related deaths in the present study.

Complications

Nearly one-third of patients (n = 14, 31.1%) in the microsurgical resection group experienced a complication, and they tended to aggregate, with 46% of patients who experienced complications having ≥ 2 events. These most commonly included VTE (11.1%) and new memory deficits (11.1%) that persisted at 1-year follow-up (Table 3). The former occurred independently of other complications in 3 of 5 such patients. Four patients (8.9%) developed postoperative wound infections; one that occurred in a patient who had undergone urgent reoperation for a venous infarction, whereas the remainder occurred after the initial

<table>
<thead>
<tr>
<th>TABLE 1. Descriptive data for 78 patients undergoing resection of colloid cysts</th>
<th>No. (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endoscopic, n = 33</strong></td>
<td><strong>Microsurgery, n = 45</strong></td>
</tr>
<tr>
<td>Age in yrs</td>
<td>40.2 ± 15.5</td>
</tr>
<tr>
<td>Sex (F/M)</td>
<td>16/17</td>
</tr>
<tr>
<td>Cyst diam (mm)</td>
<td>11.9 ± 4.8</td>
</tr>
<tr>
<td>Cyst vol (mm³)</td>
<td>2081.0 ± 3144.9</td>
</tr>
<tr>
<td>Symptomatic</td>
<td>29 (87.9)</td>
</tr>
<tr>
<td>Evans ratio</td>
<td>0.31 ± 0.1</td>
</tr>
<tr>
<td>Obstructive hydrocephalus</td>
<td>16 (48.5)</td>
</tr>
<tr>
<td>Acute hydrocephalus†</td>
<td>0</td>
</tr>
<tr>
<td>CCRS ≥ 4‡</td>
<td>28 (93.3)</td>
</tr>
<tr>
<td>EVD preop</td>
<td>6 (18.2)</td>
</tr>
</tbody>
</table>

Diam = diameter.
The percentages will not always add up, because data were not available for all patients. Thus, the percentages are calculated based on the sample size for each variable.

* Continuous variables are reported as the mean ± SD.
† Defined as hydrocephalus with symptom onset or acute progression from baseline within 24 hours of presentation (see Methods).
‡ For CCRS criteria see Beaumont et al., 2016.²

| TABLE 2. Procedural comparison for 78 patients undergoing resection of colloid cysts |
|---|---|---|
| **Endoscopic, n = 33** | **Microsurgery, n = 45** | **p Value** |
| OR time (hrs)† | 3.0 ± 0.9 | 5.2 ± 1.3 | <0.001 |
| Residual cyst wall | 21 (63.6) | 8 (19.0)‡ | <0.001 |
| Septostomy | 29 (87.9) | 15 (33.3) | <0.001 |
| EVD postop | 9 (27.3)§ | 16 (35.6) | 0.472 |
| Complications | 2 (6.1) | 14 (31.1) | 0.009 |
| LOS (days) | 4.1 ± 1.9 | 8.9 ± 7.5 | <0.001 |
| Discharge home | 33 (100) | 34 (75.6) | 0.008 |
| Procedure-related death | 0 | 0 | — |

— = either RR could not be calculated due to a continuous variable or there were no data (i.e., procedure-related death).
Boldface type indicates statistical significance.
* Continuous variables are reported as the mean ± SD.
† Time from anesthesia induction to removal of sterile drapes.
‡ Data not available for 3 microsurgical cases; thus, denominator for this entry was 42.
§ Significant decrease over time: 44% in first 16 cases versus 13% in second-half cases (p = 0.023).

| TABLE 3. Complications and reoperation during resection of colloid cysts | No.* |
|---|---|---|
| **Endoscopic, n = 33** | **IHTC, n = 35** | **TCTV, n = 10** |
| Persistent memory deficit† | 2 | 2 | 3 |
| VTE | 0 | 3 | 2 |
| Periop hemorrhage‡ | 0 | 3 | 1 |
| Seizures | 0 | 3 | 1 |
| Infection | 0 | 3 | 1 |
| Reop for complication | 0 | 7 | 2 |
| Reop for cyst recurrence | 3 | 2 | 0 |

* Note: > 1 complication in some patients.
† Defined as new memory deficit present at 1-year follow-up.
‡ Includes venous infarction (n = 3) and intraventricular hemorrhage (n = 1).
surgery. Venous infarction occurred in 3 patients in the microsurgical resection group (6.7%), all of whom had undergone an IHTC approach, whereas intraventricular hemorrhage occurred in a single patient (2.2%) who had undergone a TCTV approach. All 4 patients with perioperative hemorrhage had at least 1 additional complication—most commonly seizures, which occurred in 3 of 4 cases. The combination of infection and perioperative hemorrhage required return to the operating room in 7 patients (15.6%) in the microsurgical resection group. Two additional patients who underwent microsurgical resection delayed return to the operating room 20 and 31 days postoperatively for endoscopic septostomy due to unilateral trapped ventricle causing headache. Persistent memory deficits at 1-year postoperative follow-up were seen in 2 patients in the endoscopic resection group compared to 5 patients in the microsurgical resection group (6.3% vs 12.2%, p = 0.456). There were no other immediate or delayed perioperative complications in the endoscopic resection group.

Analysis of variables potentially associated with the occurrence of complications other than surgical approach was performed to identify independent predictors and assess for interactions. Univariate analysis suggested a significant association of surgical approach, with 6.1% and 33.1% complication rates in endoscopic resection versus microsurgical resection, respectively (p < 0.003, RR 5.1) (Table 4). Surgeon experience of ≤ 3 colloid cyst cases also trended toward association with the occurrence of complications, but did not achieve statistical significance (p < 0.083, RR 2.52). On multivariate analysis, only surgical approach remained an independent predictor of complications during surgery for colloid cysts (p = 0.015, OR 7.35, β = 2.9). When the aforementioned 2 factors were further investigated with stepwise logistic regression, the effect size of surgical approach was reduced 7.2% by surgical experience, suggesting a minimal contribution as a confounder.

### Clinical Outcomes

All patients were followed with surveillance neuroimaging at 3 months, 6 months, and 1 year postoperatively. Following this, patients underwent yearly imaging and clinic follow-up. Four patients (5.1%) were lost to follow-up after surgery. The mean follow-up duration was significantly shorter for the endoscopic resection group compared to the microsurgical resection group (3.1 ± 2.8 vs 4.9 ± 4.1 years, p < 0.016) (Table 5), reflecting the more recent adoption of the endoscopic technique at our institution. As stated above, the rate of persistent memory deficits at 1-year follow-up was reduced by nearly half in the endoscopic resection subgroup (6.3% vs 12.2%), but did not achieve significance due to relatively few events. Notably, radiographic cyst recurrence appeared to be more frequent in the endoscopic resection subgroup (22.6% vs 7.1%, p = 0.061, RR 1.8), although this was not associated with a significantly increased rate of reoperation (9.1% vs 4.7%, p = 0.347) due to relatively few events. Both patients in the microsurgical resection group who had recurrence were symptomatic at the time of presentation due to obstructive hydrocephalus causing headache. One patient

### TABLE 4. Factors associated with complications during surgery for colloid cysts

<table>
<thead>
<tr>
<th>Complication (%)*</th>
<th>Univariate</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, n = 18</td>
<td>42.4 ± 14.9</td>
<td>36.8 ± 15.9</td>
</tr>
<tr>
<td>No, n = 60</td>
<td>30/30</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Sex (F/M)</td>
<td>7/11</td>
<td>0.197</td>
</tr>
<tr>
<td>Cyst diam (mm)</td>
<td>12.7 ± 6.4</td>
<td>11.4 ± 4.1</td>
</tr>
<tr>
<td>Evans ratio</td>
<td>0.32 ± 0.08</td>
<td>0.31 ± 0.06</td>
</tr>
<tr>
<td>Obstructive hydrocephalus</td>
<td>8 (44.4)</td>
<td>29 (48.3)</td>
</tr>
<tr>
<td>Acute hydrocephalus</td>
<td>3 (16.7)</td>
<td>2 (3.3)</td>
</tr>
<tr>
<td>Approach (endo/micro)</td>
<td>2/16</td>
<td>31/29</td>
</tr>
<tr>
<td>Surgeon experience†</td>
<td>4 (22.2)</td>
<td>5 (8.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p Value</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, n = 18</td>
<td>0.95</td>
<td>0.256</td>
</tr>
<tr>
<td>No, n = 60</td>
<td></td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Univariate</td>
<td></td>
<td>0.197</td>
</tr>
<tr>
<td>Multivariate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Endo = endoscopic; micro = microsurgical.
Boldface type indicates statistical significance.
* Continuous variables are reported as the mean ± SD. Maximum likelihood could not be estimated for Evans ratio and acute hydrocephalus.
† Primary surgeon experience with ≤ 3 colloid cyst cases.

### TABLE 5. Outcome data for 78 patients undergoing resection of colloid cysts

<table>
<thead>
<tr>
<th>No. (%)</th>
<th>Endoscopic, n = 33</th>
<th>Microsurgery, n = 45</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean FU (yrs) ± SD</td>
<td>3.1 ± 2.8</td>
<td>4.9 ± 4.1</td>
<td>0.016</td>
</tr>
<tr>
<td>Persistent memory deficit</td>
<td>2 (6.1)</td>
<td>5 (11.1)</td>
<td>0.456</td>
</tr>
<tr>
<td>Recurrence</td>
<td>7 (21.2)</td>
<td>3 (6.7)</td>
<td>0.061</td>
</tr>
<tr>
<td>Symptomatic recurrence</td>
<td>0</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Time to recurrence (yrs) ± SD</td>
<td>2.7 ± 2.4</td>
<td>3.2 ± 3.2</td>
<td>0.758</td>
</tr>
<tr>
<td>Reop for recurrence</td>
<td>3 (9.1)</td>
<td>2 (4.4)</td>
<td>0.347</td>
</tr>
<tr>
<td>Reop for complication</td>
<td>0</td>
<td>8 (17.8)</td>
<td>—</td>
</tr>
<tr>
<td>Reop overall*</td>
<td>3 (9.1)</td>
<td>10 (22.2)</td>
<td>0.108</td>
</tr>
<tr>
<td>Delayed CSF diversion</td>
<td>2 (6.1)</td>
<td>4 (8.9)</td>
<td>&gt;0.99</td>
</tr>
</tbody>
</table>

FU = follow-up.
Boldface type indicates statistical significance.
* Includes reoperation for all perioperative complications including delayed obstructive webs.
underwent endoscopic resection, whereas the second underwent shunting only. Conversely, all 3 patients with endoscopic resection who experienced recurrence underwent elective endoscopic reoperation due to progressive growth on surveillance imaging, in the absence of new symptoms. There were no complications associated with endoscopic reoperation. The mean time to recurrence was similar in both the endoscopic resection and microsurgical resection groups (2.7 ± 2.4 vs 3.3 ± 3.2 years, p = 0.758). There was no significant difference in the rate of delayed postoperative CSF diversion (6.3% vs 8.9%). No deaths were identified upon query of the National Death Index.

**Total Inpatient Cost**

The consumer price index–adjusted total inpatient cost—expressed here in thousands of US dollars—was reduced by 52.6% on average for the endoscopic resection compared to the microsurgical resection ($22.5 ± 6.3 vs $47.5 ± 34.7, p < 0.001) (Table 6). There was a notably large variance associated with the cost of microsurgery, suggesting additional contributory factors. Further subgrouping demonstrated the significant impact of complications on procedure-related cost. When patients with complications were excluded, there was a 28% reduction in average inpatient cost for endoscopic resection compared to microsurgical resection ($22.5 ± 6.3 vs $31.3 ± 14.7, p = 0.007). However, the total inpatient cost for microsurgical resection when complications occurred was 4-fold (400%) greater compared to endoscopic resection ($22.5 ± 6.3 vs $90.9 ± 33.0, p < 0.001). The reduction in inpatient cost associated with endoscopic resection compared to microsurgical resection remained during reoperation for recurrence ($34.8 ± 4.4 vs $71.2 ± 4.6), although these data are based on relatively few cases (n = 5).

**Discussion**

Colloid cysts of the third ventricle can have dramatic clinical presentation and represent a technical neurosurgical challenge. Although they have historically been approached microsurgically, more recently neuroendoscopy has demonstrated favorable outcomes with shorter hospital stay and markedly decreased complication rates, as further supported by the findings of the present study.10–13 For nearly all study endpoints endoscopic resection was more favorable than microsurgical resection. The endoscopic group had significantly reduced operative time, LOS, and need for discharge to inpatient rehabilitation. Importantly, endoscopic resection eliminated major complications that were quite frequent in the microsurgical resection group, consistent with several prior reports.1,5,7,10,14,15,26 and here we demonstrate that this effect was not confounded by surgeon experience. Furthermore, not only did endoscopic resection have increased safety and shorter LOS, we show for the first time that these benefits come with > 50% reduction in total inpatient cost. The latter cannot be overlooked, given increasing pressure on surgeons by health systems to contain the cost of surgical care.

The relatively high rate of complications associated with the microsurgical resection of colloid cysts in the present study was notable, yet unsurprising. Nearly one-third of patients in the microsurgical resection subgroup experienced a complication, consistent with several prior studies reporting complication rates from 3.5% to 33% (mean 19.1% ± 13.2%).27 In the present study, complications most commonly included persistent memory deficits, VTE, perioperative hemorrhage, and infection, with the latter two requiring return to the operating room in 7 patients (15.6%). In contrast, there were no immediate perioperative complications in the endoscopic resection group, although 2 patients (6.1%) experienced persistent memory deficits. Although a recent analysis of an administrative claims database suggested similar complication profiles between the endoscopic and microsurgical approaches, total admission costs and aggregated 90-day postdischarge costs were significantly greater for microsurgically treated patients experiencing ≥ 1 complication, suggesting that these patients had more severe complications.28 Given the inherent selection bias of administrative database studies, particularly when only privately insured patients are captured—as in the abovementioned study—it is challenging to appreciate the generalizability of these data. Nonetheless, these data appear to be consistent with our finding that endoscopic resection is more cost-effective, particularly in the setting of complications.

Interestingly, our microsurgical cohort included a comparatively large number of surgeons (n = 12) with a wide range of experience, whereas the endoscopic procedures typically included 2 attending surgeons, at least 1 of whom was an expert neuroendoscopist. Although surgeon experience with colloid cysts trended toward an association with the rate of complications on univariate testing, it was not significant on multivariate analysis. The adoption of a team approach with 2 attending neurosurgeons, including at least 1 expert neuroendoscopist, may have contributed to the relatively low complication rate in the endoscopic

---

**TABLE 6. Cost of resection of colloid cysts**

<table>
<thead>
<tr>
<th>Cost in Thousands of US$*</th>
<th>Endoscopic</th>
<th>Microsurgery</th>
<th>% Δ</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cases</td>
<td>22.493 ± 6.246</td>
<td>47.463 ± 34.648</td>
<td>−0.53</td>
<td>0.0003</td>
</tr>
<tr>
<td>Cases w/o complications</td>
<td>22.493 ± 6.246</td>
<td>31.329 ± 14.712</td>
<td>−0.28</td>
<td>0.0070</td>
</tr>
<tr>
<td>Cases w/ complications</td>
<td>22.493 ± 6.246</td>
<td>90.861 ± 33.020</td>
<td>−0.75</td>
<td>0.0003</td>
</tr>
<tr>
<td>Reop</td>
<td>34.835 ± 4.347</td>
<td>71.228 ± 45.560.3</td>
<td>−0.51</td>
<td>0.3000</td>
</tr>
</tbody>
</table>

Δ = change. * Costs are expressed as the mean ± SD. All economic data were adjusted for consumer price index. Gross domestic product deflator was also assessed and was not significantly different.
Stepwise logistic regression suggested a minimal contribution of surgeon experience to the overall complications rate. Indeed, after accounting for other potential contributory factors, surgical approach was the only independent predictor of complications. Nonetheless, it is noteworthy that when less experienced surgeons encountered a complication, it was always during a microsurgical approach. This finding is consistent with the fact that over time, the endoscopic case volume became concentrated among only 2 surgeons, with the senior surgeon having participated in 94% of the endoscopic procedures. This represented a 3-fold greater colloid cyst case volume than for the highest-volume surgeon in the microsurgical resection group. Furthermore, over the study interval between 2008 and 2010, there was a transition in approach selection from exclusively microsurgical resection to primarily endoscopic resection. Prior to this transition, 95.3% (41/43 cases) were treated microsurgically, whereas after the transition 88.6% (31/35 cases) were treated endoscopically (p < 0.001) (Fig. 2).

In contrast to the abovementioned benefits, endoscopic resection was associated with a 3-fold increased frequency of coagulated residual cyst wall remnants in the present study (63.6% vs 19%). This is consistent with early case series reporting residual cyst wall remnants in 50%–70% of patients who underwent endoscopic resection. The significance of residual cyst wall following endoscopic resection remains unclear, and this is particularly the case when the remnant is small and thoroughly coagulated. Reported colloid cyst recurrence rates in the setting of coagulated cyst wall remnants range widely from 11.1% to 33.3%, although the latter rate was based on relatively few cases.

In a recent well-powered single-center study of patients who underwent surgery via flexible endoscopy, extent of resection (EOR) was categorized as en bloc removal (grade I), complete removal of the cyst contents and > 50% (grade II) or < 50% (grade III) resection or coagulation of the cyst wall. There were no recurrences in patients with grade I or II resections, with a median follow-up of 10.3 years, challenging the notion that coagulated cyst wall remnants lead to cyst recurrence. In the present study, reoperation for recurrence was nearly twice as frequent for endoscopic resection compared to microsurgical resection (9.1% vs 4.7%, p = 0.347) (Table 5); however, the difference was not statistically significant due to relatively few events. Nonetheless, the mean follow-up was also significantly shorter in the endoscopic group (3.1 years vs 4.9 years), so additional recurrences may be seen during extended follow-up. Although the mean time to cyst recurrence in the present study was 2.2 years, consistent with the prior report by Boogaarts et al., other reports with extended follow-up have demonstrated a mean time to recurrence of > 7 years, with late recurrences out to 15 years. Thus, determining the actual rate of cyst recurrence will require extended follow-up for at least 10 years.

It is possible that cyst wall remnants are more readily appreciated with the enhanced endoscopic visualization, as compared to the microscope, from “within the doorway” as opposed to outside of it. This may further confound retrospective studies such as the present one. Whatever the actual frequency of cyst wall remnants and the associated recurrence rates may be, complete removal should be undertaken to avoid potential delayed recurrence, so long as it can be done safely. As reported by Hoffman et al., even with a 6.9% overall rate of recurrence after endoscopic resection, there was an increased frequency of recurrence in cases with coagulated cyst wall remnants (33%, 3/9 patients) compared to those with complete cyst resection.

FIG. 2. Bar graph showing the evolution of approach selection for resection of colloid cysts of the third ventricle. A distinct transition of approach selection occurred between 2008 and 2010, from exclusively microsurgical resection (MR; red bars) to primarily endoscopic resection (ER; blue bars). The 3-year rolling average complication rate is also shown.
dissection. In cases in which the cyst pedicle is posteri-
with the benefit of true bimanual technique and dry-field
based approaches that offer a minimally invasive approach
study, between single burr hole endoscopic resection and
loid cysts. Although it is beyond the scope of the present
 tion, particularly because endoscopic EOR has contin-
ued to improve as bimanual endoscopic techniques have
vanced. Given the rarity of the lesion, this question can
ly be objectively addressed with a prospective, multi-
center registry that includes preoperative grading, clearly
defined indications for surgery, strict criteria for defining
postoperative residual cyst wall remnants and EOR, neu-
ropsychological testing, and patient satisfaction scores.
Despite the statistics and ongoing debate, it seems unlikely
that one surgical approach will prove superior for all col-
loid cysts. Although it is beyond the scope of the present
study, between single burr hole endoscopic resection and
traditional microsurgical resection, there are hybrid port-
based approaches that offer a minimally invasive approach
with the benefit of true bimanual technique and dry-field
dissection. In cases in which the cyst pedicle is posterior-
ly placed, the cyst contents are firm (hypointense on T2 MR),
or the cyst wall is adherent to the fornix and/or in-
ternal cerebral veins, a true bimanual technique along with
dry-field dissection may allow for more complete resection
with increased safety.

Limitations
This study has several limitations that should be con-
sidered when interpreting the findings. Given that it was a
retrospective, single-institution study of a rare disease, the
combination of potential recall and selection bias, along
with the relatively small sample size, makes generaliz-
ability somewhat challenging. Nonetheless, the study was
appropriately powered and represents one of the larger
comparative surgical series in the literature. The transi-
tion of approach selection from microsurgical resection to
almost exclusively endoscopic resection over the study pe-
riod, as well as the implementation of the 2-surgeon team
approach that required the presence of an expert neuro-
endoscopist are additional key considerations. Instead of
endoscopic resection and microsurgical resection cases
being equally distributed over time, there were essentially
3 epochs: microsurgical, transitional, and endoscopic. This
confounds the overall interpretation, because surgeon ex-
perience, surgical strategy, and technology continued to
evolve. However, this was partially mitigated by the fact
that both neuroendoscopists were present throughout the
study and performed both microsurgical and endoscopic
cases. Consistent with this notion, multivariate analysis
suggested that surgeon experience was only a weak con-
founder of surgical approach as an independent predictor
of complications.

Conclusions
Endoscopic resection of colloid cysts of the third ven-
tricle is associated with a marked reduction in perioperative
complications when compared to microsurgical resection.
It optimizes nearly all procedure-related variables and re-
duces total inpatient cost by > 50%. This cost-effective-
ness is even more pronounced in the setting of complica-
tions, and is maintained during reoperation. Endoscopic
resection is associated with an increased likelihood of
coagulated cyst wall remnants compared to microsurgical
resection, although this may not result in a significantly in-
creased rate of reoperation for recurrence. Taken together,
these findings suggest that endoscopic resection represents
an attractive minimally invasive approach for appropri-
ately selected colloid cysts.

Acknowledgments
We thank Matthew Holt (www.bodyrender.com) for his as-
sistance with the original artwork, and Joshua Osbun, MD, for
his critical review of the manuscript.

References
treatment of third ventricular colloid cysts by interhemi-
spheric far lateral transcallosal approach—experience of 134
2. Beaumont TL, Limbrick DD Jr, Rich KM, Wippold FI II,
Dacey RG Jr. Natural history of colloid cysts of the third ven-
cysts: experience with the management of 84 cases since the
introduction of computed tomography. Neurosurgery. 1989;
24(5):693-700.
4. King WA, Ullman JS, Frazee JG, Post KD, Bergsneider M.
Endoscopic resection of colloid cysts: surgical considerations
using the rigid endoscope. Neurosurgery. 1999;44(5):1103-
1111.
5. Desai KI, Nadkarni TD, Muzumdar DP, Goel AH. Surgical
management of colloid cyst of the third ventricle—a study of
6. Milligan BD, Meyer FB. Morbidity of transcallosal and
transcortical approaches to lesions in and around the lateral
and third ventricles: a single-institution experience. Neuro-
7. Sheikh AB, Mendelson ZS, Liu JK. Endoscopic versus mi-
crosurgical resection of colloid cysts: a systematic review and
meta-analysis of 1,278 patients. World Neurosurg. 2014;82(6):
1187-1197.
8. Gronndin RT, Hader W, MacRae ME, Hamilton MG. Endo-
escopic versus microsurgical resection of third ventricle col-


Disclosures
Dr. Limbrick receives support for a non–study-related clinical or research effort that he oversees from Medtronic, Inc., and Microbot Medical, Inc.

Author Contributions

Correspondence
Thomas L. Beaumont: University of California, San Diego, La Jolla, CA. tbeaumont@health.ucsd.edu.