Endovascular treatment of intracranial aneurysms by using Guglielmi detachable coils in awake patients: safety and feasibility

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Object. Embolization of intracranial aneurysms performed using Guglielmi detachable coils (GDCs) is performed with the patient in a state of general anesthesia at most centers. Such an approach does not allow intraprocedural evaluation of the patient’s neurological status and carries additional risks associated with general anesthesia and mechanical ventilation. At the authors’ institution, GDC embolization of intracranial aneurysms is performed in awake patients after administration of sedative and analgesic agents (midazolam, fentanyl, morphine, and/or hydromorphone). To determine the feasibility and safety of this approach, the authors have retrospectively reviewed their clinical experience.

Methods. The authors reviewed the medical records of all patients in whom GDC embolization for the treatment of intracranial aneurysms was undertaken between February 1, 1990 and October 31, 1999. Clinical presentation, medical comorbidities, anesthetic agents used, intraprocedural complications, and final procedural outcome were recorded for each patient.

Guglielmi detachable coil embolization was attempted in the awake patient in 150 procedures. Among 92 procedures for unruptured aneurysms, 75 (82%) were completed without complications. Four procedures were completed with complications. Of the 92 procedures, 13 were aborted due to patient uncooperativeness (one patient), complications (three patients), morphological characteristics of the aneurysm or surrounding vessels that made embolization technically difficult (eight patients), or vasospasm (one patient). Among 58 procedures for ruptured aneurysms, the procedure was completed without complication in 48 cases (83%). The procedure was completed with complications in five cases and two patients required induction of general anesthesia during the procedure. Five procedures were aborted because morphological characteristics of the aneurysm or surrounding vessels made embolization technically difficult (two patients) or because of aneurysm rupture (two patients) or the appearance of a transient neurological deficit (one patient).

Conclusions. Embolization of intracranial aneurysms performed using GDCs in the awake patient appears to be safe and feasible and allows intraprocedural evaluation of the patient. Potential advantages, including decreased cardiopulmonary morbidity rates, shorter hospital stay, and lower hospital costs, still require confirmation by a direct comparison with other anesthetic procedures.

Key Words • anesthesia • intracranial aneurysm • subarachnoid hemorrhage • Guglielmi detachable coil

Guglielmi detachable coil embolization has recently emerged as a treatment modality for intracranial aneurysms. The coils are delivered using an endovascular approach that does not involve extensive surgical excision and, therefore, administration of general anesthesia is not mandatory. Other interventionists have performed GDC embolization in patients in a state of general anesthesia. However, this approach does not allow intraprocedural evaluation of the patient’s neurological status and carries additional risks associated with general anesthesia and mechanical ventilation. Although GDC embolization can be performed in awake patients, the safety and feasibility of this approach has not been previously reported. At our institute, GDC embolization is performed in awake patients whenever possible. We retrospectively reviewed our procedural results to determine the feasibility and safety of using this strategy to perform intracranial aneurysm embolization.

Clinical Material and Methods

Patient Population and Data Collection

Using a computerized registry maintained by the Department of Neurosurgery, we identified patients who had been scheduled for GDC embolization of intracranial
Guglielmi detachable coil embolization in awake patients

aneurysms at the Millard Fillmore Hospital in Buffalo, New York, between February 1, 1990 and October 31, 1999. We collected the following information from each patient’s medical records and operative reports: 1) patient age, sex, and race, as determined by the triage clerk; 2) presenting symptoms, including whether the aneurysm had ruptured; 3) neurological deficits at admission, including the initial GCS score; 4) onset of symptoms in patients with subarachnoid hemorrhage; 5) location and size of intracranial aneurysms; 6) timing of GDC (GDC; Boston Scientific/Target Therapeutics, Fremont, CA) embolization from onset of subarachnoid hemorrhage; 7) anesthetic agents used during the embolization procedure; 8) number of coils used; 9) intraprocedural complications, including aneurysm rupture; 10) procedural outcome with regard to technical success; 11) underlying reasons for technically unsuccessful procedures; 12) length of ICU and hospital stays; 13) procedure-related morbidity, defined as permanent neurological deficits attributed to intraprocedural complications; and 14) procedure-related mortality, defined as death attributed to intraprocedural complications.

Protocol for GDC Embolization

The patients’ heart rate, electrocardiographic data, blood pressure, respiratory rate, and oxygen saturation were continuously monitored. A nurse specializing in neurological critical care was available throughout the procedure for patient monitoring and administration of medication. Arterial access was achieved via percutaneous puncture of the femoral artery. A heparin bolus was intravenously administered to achieve an ACT longer than 250 seconds in patients with unruptured aneurysms. Patients with ruptured aneurysms received a lower dose of intravenous heparin to achieve an ACT of approximately 200 seconds. After the first one or two coils were delivered, a second dose of heparin was administered to achieve an ACT between 200 and 250 seconds, if necessary. For each embolization procedure, a No. 6 French (or, occasionally, a No. 5 French) guide catheter was placed in the cervical ICA or VA. A 0.014-in microguidewire and microcather with two radiopaque markers were navigated into the aneurysm cavity by using a magnified road-mapping procedure. Coils of decreasing sizes were delivered into the aneurysm cavity and electrolytically detached. Angiograms were obtained before detaching each coil to ensure preservation of the parent vessel. This process was continued until maximum angiographically confirmed obliteration of the aneurysm cavity was achieved.

Protocol for Anesthesia

Whenever appropriate, GDC procedures were performed while the patient was in an awake state by using the following approach. Local anesthesia was introduced by percutaneous infiltration of 1% lidocaine into the subcutaneous tissue around the femoral artery. Patients received a sedative agent (intravenous midazolam, 1–2 mg) at the initiation of the procedure. Intravenous fentanyl, morphine, or hydromorphone was administered intermittently for pain control. Patients who were unable to undergo the procedure in an awake state were intubated and underwent mechanical ventilation. These included patients with ruptured intracranial aneurysms and poor neurological status (GCS Score ≤ 8 at the time of the procedure). Almost all these patients had already been intubated. Patients with altered sensoria who were unable to follow verbal commands were electively intubated before the procedure and following evaluation by the treating physician. Infrequently, patients harboring an unruptured aneurysm who were unable to tolerate a prolonged supine position due to psychological or musculoskeletal diseases were treated after general anesthesia was induced. Intravenous general anesthesia was administered by the nursing staff by using fentanyl or midazolam with a concomitant neuromuscular blockade achieved using pancuronium under the direction of the operating neurosurgeon. Infrequently, inhalational anesthetic agents were administered for the procedure by a member of the anesthesia service.

Presentation of Data

Data for groups are presented as the means ± standard deviation.

Results

During the study period, GDC embolization was undertaken during 150 procedures in 137 patients in an awake state. Of the 137 patients, 11 underwent two separate procedures and one patient underwent three separate procedures performed using local anesthesia. Another six patients underwent a second procedure that was performed while they were in a state of general anesthesia, and two patients had undergone previous procedures that had been performed while they were in a state of general anesthesia. In 43 patients procedures were performed after induction of general anesthesia. General anesthesia was induced and maintained using inhalational anesthetic agents in 11 procedures (three for unruptured aneurysms), whereas in 32 procedures (29 procedures for ruptured aneurysms and three procedures for unruptured aneurysms) a combination of fentanyl, midalozam, and neuromuscular blockade was used. Embolization was attempted in awake patients during 92 procedures (80 patients) for unruptured aneurysms. Aneurysms were located in the ICA in 26 patients, the MCA in 11 patients, the ACA in one patient, the ACoA in four patients, the PCA in one patient, the VA in two patients, the BA in 20 patients, the PCA in nine patients, and other sites in six patients. Coil embolization of aneurysms was assisted by stent placement in nine patients (nine procedures). Two of the these patients had undergone stent placement during a separate previous procedure. Of the 92 procedures for unruptured aneurysms, procedures were successfully completed without complications in 75 cases (82%). A total of 13 procedures were aborted; this was due to uncooperativeness in one patient, clinical complications in three patients, morphological characteristics of the aneurysm or surrounding vessels that made embolization technically difficult in seven patients, coil displacement in one patient, and vasospasm in one patient (Table 1). Seven procedures were complicated (including the aforementioned three aborted cases), by neurological symptoms in two patients and by extravasation of contrast agent into the subarachnoid space, uncontrolled hypertension, severe nausea and emesis, angi-
na, and hypotension with coil displacement in one patient each. Emergency intubation with sedation and neuromuscular blockade was required in one patient who underwent a complicated procedure that was subsequently aborted. Among patients with unruptured aneurysms, the mean postoperative ICU stay per admission was 2.9 ± 4 days, and the mean hospital stay per admission was 6.6 ± 9 days. The frequency of postprocedural ICU and hospital stays is shown in Fig. 1. A mean of 5.2 ± 4.5 coils per procedure were delivered. Procedure-related morbidity and mortality rates were 2% and 0%, respectively.

Guglielmi detachable coil embolization was undertaken in awake patients during 58 procedures for 59 ruptured aneurysms. These aneurysms were located in the ICA in 10 patients, the MCA in six patients, the ACA in one patient, the ACoA in six patients, the PCoA in eight patients, the VA in three patients, the BA in 14 patients, the PCA in two patients, and other sites in eight patients. In one patient, coil placement in two intracranial aneurysms was performed during the same procedure. The mean admission GCS score was 10.9 ± 4.3. The procedure was successfully completed without complication in 48 (83%) of the 58 procedures. The procedure was completed with complications in five cases; in two of these induction of general anesthesia was required during the procedure. Five procedures were aborted because the morphological characteristics of the aneurysm or surrounding vessels made embolization technically difficult (two patients) or because of aneurysm rupture (two patients) or the appearance of a transient neurological deficit (one patient; Table 2). Among patients with ruptured aneurysms, the mean postoperative ICU stay was 11.2 ± 14.5 days and the mean hospital stay was 20.6 ± 24.9 days. The distribution of postprocedural ICU and hospital stays is shown in Fig. 2. A mean number of 4.6 ± 4.3 coils per procedure were delivered. Procedure-related morbidity and mortality rates were 1.6% and 3%, respectively.

Guglielmi detachable coil embolization was undertaken in 43 patients after general anesthesia had been induced. The aneurysms were located in the ICA in nine patients, the MCA in five patients, the ACA in four patients, the ACoA in five patients, the PCoA in two patients, the VA in one patient, the BA in 14 patients, the PCA in two patients, and another site in one patient. The procedure was completed with complications arising in two cases, aneurysm rupture in one patient and occlusion of the MCA in the other. Four procedures were aborted because morphological characteristics of the aneurysm or surrounding vessels made embolization technically difficult in three patients and there was aneurysm rupture in another patient. Among patients with ruptured aneurysms, the mean postoperative ICU stay was 17.5 ± 13.8 days and the mean hospital stay was 30.5 ± 22.2 days. Among patients with unruptured aneurysms, the mean postoperative ICU stay was 10.7 ± 11.8 days and the mean hospital stay was 20.5 ± 19 days. A mean of 6.4 ± 5.7 coils per pro-

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**TABLE 1**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Site</th>
<th>Complications or Reasons for Aborted Procedure</th>
<th>Procedural Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>59, F</td>
<td>BA</td>
<td>bilat loss of vision w/ decreased filling in both PCAs</td>
<td>converted to GA, GDC treatment aborted, intraarterial urokinase in both PCAs</td>
<td>aborted</td>
</tr>
<tr>
<td>2</td>
<td>60, F</td>
<td>ICA</td>
<td>upper extremity weakness followed by focal seizures</td>
<td>aborted, treated w/ intravenous midazolam &amp; postop heparin</td>
<td>aborted</td>
</tr>
<tr>
<td>3</td>
<td>45, F</td>
<td>MCA</td>
<td>hypertension</td>
<td>completed</td>
<td>completed</td>
</tr>
<tr>
<td>4</td>
<td>49, F</td>
<td>PICA</td>
<td>vasospasm</td>
<td>aborted, completed later</td>
<td>completed</td>
</tr>
<tr>
<td>5</td>
<td>59, F</td>
<td>ICA</td>
<td>uncooperative patient</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>6</td>
<td>47, F</td>
<td>ICA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>7</td>
<td>69, F</td>
<td>MCA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>8</td>
<td>57, F</td>
<td>PCA</td>
<td>coil displacement</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>9</td>
<td>56, M</td>
<td>MCA</td>
<td>intraop vasospasm</td>
<td>completed</td>
<td>completed</td>
</tr>
<tr>
<td>10</td>
<td>54, F</td>
<td>ICA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>11</td>
<td>66, F</td>
<td>PCA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>12</td>
<td>78, F</td>
<td>PCA</td>
<td>angina</td>
<td>aborted; angina resolved w/ nitroglycerin, furosemide, &amp; morphine treatment</td>
<td>aborted</td>
</tr>
<tr>
<td>13</td>
<td>60, F</td>
<td>BA</td>
<td>severe nausea &amp; emesis</td>
<td>completed</td>
<td>completed</td>
</tr>
<tr>
<td>14</td>
<td>40, F</td>
<td>PCoA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>15</td>
<td>49, F</td>
<td>ICA</td>
<td>displaced coils, hypotension</td>
<td>completed</td>
<td>completed</td>
</tr>
<tr>
<td>16</td>
<td>79, F</td>
<td>ACoA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
<tr>
<td>17</td>
<td>44, F</td>
<td>ICA</td>
<td>DMC</td>
<td>aborted</td>
<td>aborted</td>
</tr>
</tbody>
</table>

* DMC = difficult (to treat) morphological characteristics; GA = general anesthesia; PICA = posterior inferior cerebellar artery.
procedure were delivered. Procedure-related morbidity and mortality rates were 2.3% and 2.3%, respectively.

**Discussion**

**Guglielmi Detachable Coil Embolization in Awake Patients With Unruptured or Ruptured Aneurysms**

Our findings indicate that GDC embolization can be successfully performed in awake patients. A high technical success rate was observed in patients with unruptured intracranial aneurysms and in patients with good clinical grades who harbored ruptured aneurysms. Among the 150 procedures performed for unruptured or ruptured aneurysms, successful GDC embolization was accomplished without complications in 123 procedures. Another 9 procedures were completed with complications and 18 procedures were aborted. It should be recognized that this approach cannot be used in some patients because of their poor clinical conditions. In our hospital, 43 GDC embolization procedures were performed in patients in a state of general anesthesia during the study period, predominantly for ruptured aneurysms. The rates of technical success and intraprocedural complications were similar for both procedures; however, differences between patient characteristics preclude a direct comparison.

**Risks of General Anesthesia**

For patients with intracranial aneurysms, performance of GDC embolization in the awake patient avoids the complications associated with general anesthesia. In their review of 17,201 patients who received intraoperative general anesthesia at multiple centers, Forrest and colleagues[^3] reported 19 deaths, of which seven were related to anesthetic agents. Adverse cardiovascular events were commonly associated with general anesthesia and included tachycardia (41%), hypotension (31%), hypertension (27%), bradycardia (19%), ventricular arrhythmias (6%), and myocardial ischemia (0.4%). A total of 6.4% of the patients had severe cardiovascular outcomes requiring extensive treatment. The investigators identified a history of cardiac failure or myocardial infarction, American Society of Anesthesiologists physical status 3 or 4, nature of surgical procedure, and anesthetic agent as predictors of cardiovascular complications. Patient age, smoking history, obesity, and presence of chronic obstructive pulmonary disease also increased the risk of severe respiratory outcomes including bronchospasm and respiratory failure.[^3]

The high prevalence of cigarette smoking and cardiac diseases in patients with intracranial aneurysms may increase the risk of anesthesia-related complications.[^3] Furthermore, in patients with ruptured intracranial aneurysms and angiographically confirmed vasospasm, hemodynamic instability may provoke cerebral ischemia. Prolonged recovery from anesthesia also obscures neurological evaluation in the hours following the procedure.[^3]

In patients undergoing carotid endarterectomy, use of local anesthesia is associated with a reduction in the odds of stroke, myocardial infarction, and pulmonary complications within 30 days after the operation.[^1,5,9,14,17,20]

**Guglielmi Detachable Coil Embolization in the General Anesthesia State**

The procedure-related morbidity rates for GDC aneurysm embolization performed while a patient is in a state of general anesthesia have ranged from 3 to 17%; procedural mortality rates range from 0 to 8%. Patient characteristics and procedural results from a variety of studies[^3,6,10,12,14,21,22] are provided in Table 3. Our procedure-related morbidity and mortality rates for patients with unruptured

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inintracranial aneurysms were 2% and 0%, respectively. Similarly, the procedure-related morbidity and mortality rates for patients with ruptured intracranial aneurysms were 1.6% and 3%, respectively. Although direct comparisons cannot be made because of differences in the patient populations, our results compare favorably with those from studies in which GDC embolization has been performed while the patient was in a state of general anesthesia. Similarly, Casasco, et al.\textsuperscript{1} reported 71 patients who underwent GDC embolization using neuroleptanalgesia, except in cases requiring respiratory assistance. They reported procedure-related morbidity and mortality rates of 13% and 7%, respectively. Preliminary evidence indicates that GDC embolization can be performed while patients are in an awake state with procedure-related morbidity and mortality rates similar to those found in patients in whom the procedure is performed with general anesthesia.

Advantages of Local Anesthesia Over General Anesthesia

In addition to reducing the risk associated with general anesthesia, performing GDC embolization while the patient is in an awake state (conscious sedation) permits regular neurological evaluations throughout the procedure. In the event of a thromboembolic complication, early detection of neurological deficits and their severity allows timely and appropriate use of thrombolytic therapies. Furthermore, this approach avoids the costs of inhalational anesthetic agents, mechanical ventilation, and anesthesiology services. At our institution, the cost of anesthesia services for GDC embolization of an intracranial aneurysm is $750 for induction followed by $200 hourly for maintenance. For GDC procedures lasting approximately 3 hours, an estimated $1350 is saved per procedure. For 100 procedures, the estimated savings are $135,000 by avoiding the use of arteriography and the ICU also contributed to the cost-effective comparison. For procedures lasting approximately 3 hours, an estimated $1350 is saved per procedure. For 100 procedures, the estimated savings are $135,000 by avoiding the use of arteriography and the ICU also contributed to the cost-effective implementation of general anesthesia to minimize patient performance of GDC embolization while the patient is in the awake state reduces ICU and hospital stay.

Disadvantages of GDC Embolization in the Awake Patient

Some limitations of embolization in awake patients should be considered. Embolization in awake patients may be technically more difficult and requires the assistance of a skilled clinician for procedural monitoring and intensive care management. A potential drawback of this approach is the inability to control respiratory motion during radiographic filming. Some investigators advocate implementation of general anesthesia to minimize patient movement and any breathing artifact that would interfere with coil placement using landmarks and road mapping. We have observed that adequate immobilization can be achieved with patient cooperation to enable safe and successful intravascular manipulation. The prolonged period of immobilization can be uncomfortable for the patient, and adequate analgesia must be administered. Another emerging component of endovascular treatment of intracranial aneurysms is the use of 3D angiography, which requires multiple images at different projections performed in rapid sequence. We have limited experience with the use of 3D angiography for evaluation of intracranial aneurysms. In our preliminary experience, we have found that 3D angiography can be adequately performed in awake patients.

Conclusions

Guglielmi detachable coil treatment of intracranial an-
Guglielmi detachable coil embolization in awake patients

eurysms performed while the patient is in an awake state appears to be safe and feasible for most patients with unruptured aneurysms and for selected patients with ruptured intracranial aneurysms. This approach allows regular evaluation of the patient and avoids the risk and cost of general anesthesia. Further attempts to define a significant advantage of this method will necessitate a direct comparison with other anesthetic procedures.

References

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