OME evidence suggests that titanium clips may be inferior to cobalt alloy clips in their mechanical characteristics in contrast with their superiority in radiological features. 13 Even when a neurosurgeon possesses all information relating to a particular clip, there remain various factors to be intraoperatively evaluated to eliminate the risk of clip-related destruction of the aneurysm neck. With especially large aneurysms, cross-sectional areas determined using radiological means may differ from measurements obtained intraoperatively and these dimensions cannot always be satisfactorily measured.

The coincidence between the introduction, during the last 3 years, of titanium clips in our department and the appearance of intraoperative slippage phenomena (four cases in a total of 132 clipped aneurysms) prompted us to review and analyze the mechanisms involved in these specific cases.

Summary of Cases

Description of the Phenomena

We observed intraoperative aneurysm clip slippage in four patients (three women and one man, aged 33–70 years), all of whom harbored an ICA aneurysm (three aneurysms on the right side and one on the left). The aneurysms (two ruptured and two unruptured) had broad necks and their cross-sectional widths were larger than 2 cm. In each case, after application of a Yaşargil titanium clip (model FT 790 T; Aesculap Instruments Corp., Tuttingen, Germany), the branches of the clip moved like a scissors and slowly rotated almost 90° to the original plane of application. In an attempt to reduce the filling pressure of the aneurysm, proximal and distal temporary ICA clipping was necessary. This maneuver allowed us to increase the closing force of the aneurysm clip, but complete aneurysm occlusion still required application of at least one additional clip and replacement of the first one.

The rapid application of a new clip parallel to the first clip and repositioning of the first clip closed the aneurysm sac in three cases (Fig. 1). In the remaining patient, the slipped clip almost sheared the wall of the aneurysm. This occurred while intraoperative angiographic guidance was in use (Fig. 2).

The patients’ postoperative courses were uneventful and they were discharged approximately 3 weeks after the operation without exhibiting new neurological deficits.

Discussion

There are some reports of patients in whom aneurysm clips have slipped after aneurysm surgery; 1,5,10,12,14 however, there are few descriptions of a scissorslike mechanism resulting in intraoperative clip rotation. We note that this intraoperative slippage phenomenon has not been observed by us in cases in which other materials such as cobalt alloy clips were used.

The cases described here share some common characteristics: 1) the first clip used in each case was straight, with a maximum closing force of 200 g; 2) the width of the aneurysm sacs was greater than 2 cm; 3) the aneurysms had broad necks and the clips slipped just after application, which allowed us to perform intraoperative clip repositioning; and 4) the same type of clip was involved in the clipping of four aneurysms located on the ICA.

In an attempt to resolve the problem of aneurysm clip slippage, several neurosurgeons have introduced varia-
Intraoperative clip slippage phenomena

Fig. 1. Case 2. Selected frames from a 50-second intraoperative video sequence of 813 captured frames. 1–3: Intraoperative ICA aneurysm view and clip application. 4–6: Scissorslike aneurysm clip slippage. Rotation of the clip branches took 7.6 seconds. 7–9: Application of a second aneurysm clip parallel to the first one and correction of the first clip, which was lying almost perpendicular to its original placement.

Fig. 2. Case 4. Left: Right lateral ICA angiogram revealing a large right carotid–ophthalmic aneurysm. Right: Intraoperative angiographic control image demonstrating that the applied titanium clip has a tendency to cross blades (arrow).

Intraoperative clip slippage phenomena will be. This factor may also be responsible for clips that display translational movements without rotation, being pushed from a high-resistance area (engrossed aneurysm wall) into a low-resistance area (parent artery). This results in occlusion or secondary narrowing of this vessel. The fifth factor is the degree of hysteresis, which is the failure of the spring to restore its elastic force at a given position after an initial displacement. Alpha clips possess no separate spring and the entire clip body is the spring; the closing force is produced by the elastic recoil of the deformation of the whole clip body. For this reason, any change in the overall geometry or configuration of the clip or its material composition will influence the force output. Our clip forceps applicator (clip-investing type) adds to the basic C-shaped rest lateral walls, which greatly reduces the possibility of any lateral sway and does not allow excessive opening of the clip branches or clip deformations.

We conclude after examining these factors that, in cases like those of our patients, the surgeon could avoid complications by using the following guidelines. 1) Use the mobile fulcrum clip type, which has the advantage that the blades do not cross and, similar to alpha clips, a lower degree of hysteresis. 2) If it is decided that an alpha titanium clip will be used, reduce the amount of aneurysm filling by decreasing blood pressure or by temporary clipping of the main vessel; this will positively affect the third, fourth, and fifth factors (as in our cases). 3) If the first clip slips off but does not rupture the aneurysm, place a second occluding clip parallel to the first and correct the blades of the first clip. 4) For broad-neck aneurysms, never use a clip that has been left open on the instrument table or re-sterilized for a subsequent operation. 5) While inserting the clip, leave a depth of at least 2 mm from the tip or deeper. This should increase the compression load. 6) The complete resection of arachnoidal bundles surrounding the aneurysm neck or the well-known use of bipolar coagulation or a silk ligature placed around the neck of the aneurysm can in some cases be necessary. Any of these actions will reduce the amount of tissue between the clip blades and positively influence the closing force. Many manufacturers standardize the clip-closing force at a blade gap of 1 mm. 7) The relationship between gap and vessel elasticity must especially be considered for ICA aneurysms or in cases in which the surgeon encounters an aneurysm with larger proportions than those observed angio-
Atherosclerotic changes in the neck should increase the blade gap, resulting in an incremental slippage risk. Temporary clipping of the parent artery performed to allow removal of atheroma before a clip is applied on the aneurysm neck requires that the surgeon possess advanced microvascular skills and does not guarantee satisfactory results. For this reason, we do not recommend its use in unruptured aneurysms. 8) The plane of clip insertion (perpendicular, parallel, or angular) to the ICA seems to determine how the clip moves (rotationally or translationally) in case of slippage. The four cases observed by us showed a tendency for the blades to cross after perpendicular insertion. 9) Before clipping, the neck resistance between the branches of the bipolar coagulator should be felt. This could help the surgeon evaluate the risk of slippage. 10) New materials tests should be performed to check titanium generation.

References