ORIGINAL ARTICLE

Modified Brooks Posterior Wiring Technique for Three-Point C1-C2 Arthrodesis

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ABSTRACT: ***Background:*** The optimal surgical treatment of atlanto-axial instability remains controversial despite the variety of modifications and supplemental techniques currently available. ***Methods:*** We describe a modification of the Brooks posterior wiring technique supplemented with transarticular screws for C1-C2 instability. ***Results:*** This method has been implemented in 30 patients in our institution with no radiological failures. ***Conclusions:*** The modification provides several technical advantages and potentially stronger fixation compared to methods currently in use.

RÉSUMÉ: Technique modifiée de cerclage postérieur de Brooks pour l'arthrodèse C1-C2 en trois points. ***Introduction:*** Le meilleur traitement chirurgical de l'instabilité atlanto-axiale demeure un sujet controversé même si une grande variété de modifications et de techniques d'appoint sont maintenant disponibles. ***Méthodes:*** Nous décrivons une modification à la technique de cerclage postérieur de Brooks avec vis transarticulaires pour traiter l'instabilité au niveau de C1-C2. ***Résultats:*** Cette méthode a été utilisée chez 20 patients dans notre institution, sans échec radiologique. ***Conclusions:*** La modification présente plusieurs avantages techniques et potentiellement une meilleure fixation comparée aux méthodes utilisées actuellement.

Can. J. Neurol. Sci. 2001; 28: 125-129

Instability of the upper cervical spine can have devastating neurological consequences. Tumors, rheumatoid arthritis, fractures, ligamentous injuries, and congenital malformations are but a few of the pathological conditions that can contribute to instability at the atlantoaxial junction, already the most mobile region of the vertebral column. Operative C1-C2 arthrodesis is required to stabilize this segment when rigid external fixation is unlikely to result in fusion.[1] The limitations and variable fusion rates following the traditional posterior wiring methods of Gallie and Brooks have resulted in the development of a variety of modifications and supplemental techniques that are now available to the spinal surgeon.[2] These include the interspinous modified Gallie or Sonntag technique,[3] Halifax interlaminar clamps,[4] and posterior transarticular screws.[5] Of these, transarticular screw fixation augmented by posterior bone grafting has become the standard of care in experienced hands.[6]

We describe a modification of the Brooks wiring technique as an adjunct for C1-C2 transarticular screw fixation, with improved versatility and theoretical biomechanical advantages over other methods. The focus of this report is to provide a detailed description of this new technique and its advantages.

OPERATIVE PROCEDURE

Following the induction of general anesthesia, skull pin fixation is applied and the patient rolled onto the operating table in a prone position (a traction device or Jackson table is not required). Under fluoroscopic control the head is positioned (with the surgeon maintaining traction) in a "military tuck", maintaining (as close as possible) normal alignment between the anterior ring of C1 and the anterior body of C2. After skin preparation, a midline incision is performed from the inion to C7. A subperiosteal exposure is performed at the base of the occiput, along the posterior ring of C1 and across the posterior elements of C2 and C3. Care is taken to preserve the facet joint capsules as well as the interspinous and supraspinous ligaments between C2 and C3. Blunt dissection is used to expose the pars interarticularis of C2 bilaterally. The paravertebral venous plexus is quite prominent in this region; bleeding is controlled with bipolar cautery, microfibrillar collagen, and gentle tamponade. The C1-C2 joint space is entered and the articular surfaces denuded carefully with curettes. A Midas Rex® drill (AM-8 cutting burr) can be used to perform further decortication, retracting the C-2 nerve root rostrally as necessary, staying well lateral to the spinal cord and medial to the vertebral arteries.

Through a separate incision, a 3x3 cm block of iliac crest is

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RECEIVED MARCH 6, 2000. ACCEPTED IN FINAL FORM MARCH 20, 2001.

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harvested, with a microsagittal saw, along with cancellous tissue from residual native bone. Morselated cancellous bone is gently tamped, under direct vision, into the C1-C2 articular interface bilaterally. The AM-8 bit on the Midas Rex® drill is used to mark entry points for transarticular screws 3-4 mm above the C2-C3 facet joint, sighting a line straight down the exposed pars interarticularis. Transarticular screw placement is as described in published reports. Briefly, under fluoroscopic control, K-wires are passed through the pars, across the C1-C2 joint space, and into the lateral masses of C-1 bilaterally.[6] The K-wires are overdrilled with a 2 mm diameter cannulated drill and self tapping cannulated titanium lag screws advanced over each K-wire under fluoroscopic guidance to ensure bicortical purchase. We have found 4.0 mm diameter screws from the DePuy ACE small fragment set to provide superior purchase.

Preparation of the fusion site is undertaken with a high speed drill. Smooth, parallel, flat surfaces are engineered inferiorly along the posterior ring of C1 and superiorly across the lamina and spinous process of C2, exposing cancellous bone (Figure 1). The tricortical iliac crest graft is contoured to fit between the residual posterior elements of C1 and C2 (Figure 2). The cortical apical surface (the superior aspect of the tricortical iliac crest graft) is removed with the microsagittal saw providing two parallel cancellous surfaces (one to abut against C1 and one to abut against C2). The posterior occipito-atlanto-axial membrane is partially resected on each side of midline, exposing the epidural space at C0-C1 and C1-C2. Similarly, small windows are created in the ligamentum flavum between C2 and C3, on each side of midline, preserving the interspinous and supraspinous ligaments. A solid titanium leader on a multistranded wire is bent into a “Lazy S” shape prior to insertion. Working in a caudal to rostral direction the leader is fed along the epidural space underneath C2 with a needle driver. After the multistranded component is advanced under C2, the procedure is repeated for C1. Care is taken to provide “upwards” tension (out of the wound, away from the dura) on both ends of the cable at all times once the leader has been captured. Alternatively, passing the blunt end of a 0-vicryl suture rostrocaudally under the posterior ring of C1 allows capture of the suture material with a blunt hook beneath C1 (Figure 3a). As the needle is removed rostrally a loop of suture material remains inferior to the C1 ring. The multistranded cable is placed through this loop (Figure 3b), which is then pulled rostrally under the ring of C1, out through the C0-C1 interspace bringing the cable with it (Figure 3c). The leader must be cut off when performing this maneuver and the cable guided under the ring of C1 flat to the dura. Cables are placed on both the left and right sides of midline (Figure 4a).

After the contoured graft is inserted into position, the cables are tightened proportionately to the overall quality of the bone (Figure 4b). Following irrigation with sterile saline, a standard layered closure is performed. Figure 5 demonstrates a postoperative radiological study depicting the completed construct. Note that postoperative immobilization in a collar is required for three months.

Presently, this modified Brooks wiring with transarticular screw fixation has been implemented in 30 patients in our institution between 1996-2001. There have been no radiographic failures or complications to date using a minimum three month follow-up and flexion-extension x-rays for all patients.

DISCUSSION

Controversy still exists regarding the optimum treatment of atlanto-axial instability. The principles of posterior wiring and bone graft fusion were introduced by Gallie in 1936.[7] Gallie, a Canadian orthopedic surgeon, never published the details of his technique and as a result was never given full recognition for the posterior wiring method. Redemption, albeit modest, occurred when his technique was described fully by McGraw and Rusch who referred to it as the “Gallie fusion”.[8] Briefly, the Gallie method passes a sublaminar cable loop under C1 only and wraps the loop under the spinous process of C2 – trapping the onlay bone graft which is secured by tightening the free ends of the cable horizontally and notched to allow footing on the C2 spinous process. Brooks and Jenkins followed in 1978 with a well-described wedge compression technique[9] that was modified

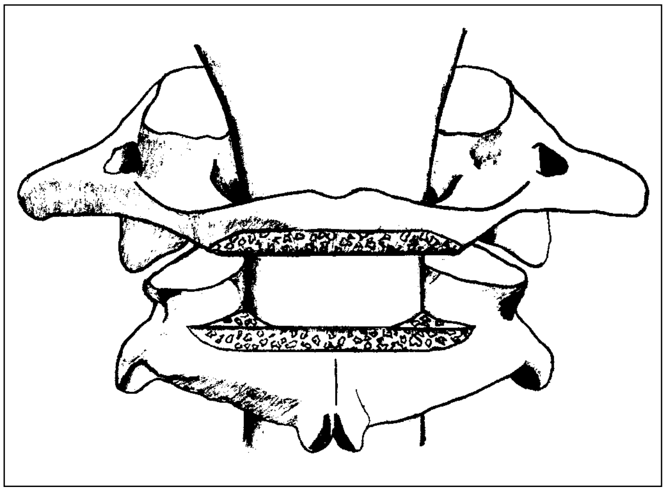

Figure 1: *Diagrammatic illustration of C1-2 preparation with smooth, flat and parallel contoured edges superiorly and inferiorly, maximizing cancellous surface area contact and directing cable tension forces in pure compression.*

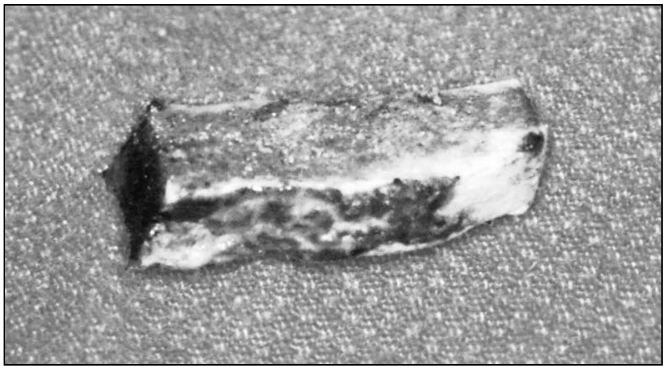

Figure 2: *Edges of the contoured graft are parallel and perpendicular, giving it a cuboidal shape. When carefully measured within a millimeter of accuracy, the graft is easily and safely slotted between the parallel contoured posterior elements of C1 and C2.*

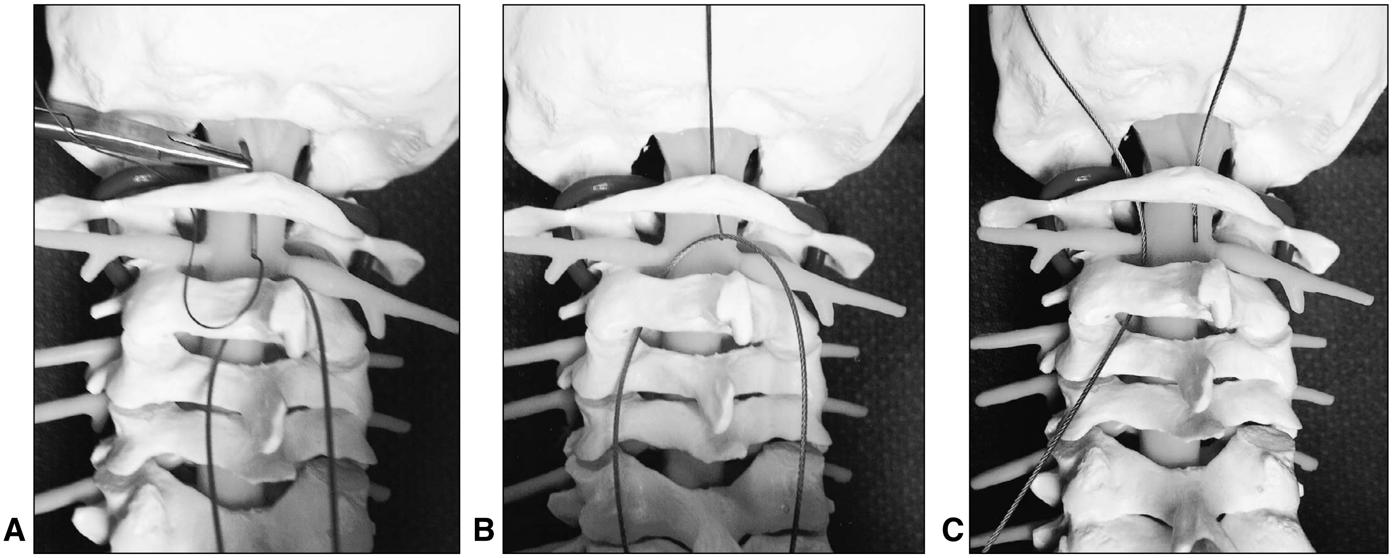

Figure 3: *Representation of the reverse suture technique for threading multistranded cable beneath the posterior ring of C1.* ***A:*** *A 0-vicryl suture on a curved tapered needle is passed in a reverse fashion (blunt end first) under the posterior arch of C1 from a rostral to caudal direction. The suture material is captured by a blunt hook as it appears from under C1.* ***B:*** *The malleable leader is cut leaving 2-3mm still attached to the cable, to reduce the risk of spinal cord damage when the cable is pulled under C1. A small section of leader must remain attached to the cable to facilitate easy passage through the tensioning device. The cable is threaded through the loop created by the suture and is turned 90 degrees so it lies tangential or parallel to the posterior arch of C1 and posterior dural surface prior to its passage.* ***C:*** *The suture-cable complex is then carefully drawn under C1 keeping the cable tangential to the thecal sac at all times to minimize dural indentation.*

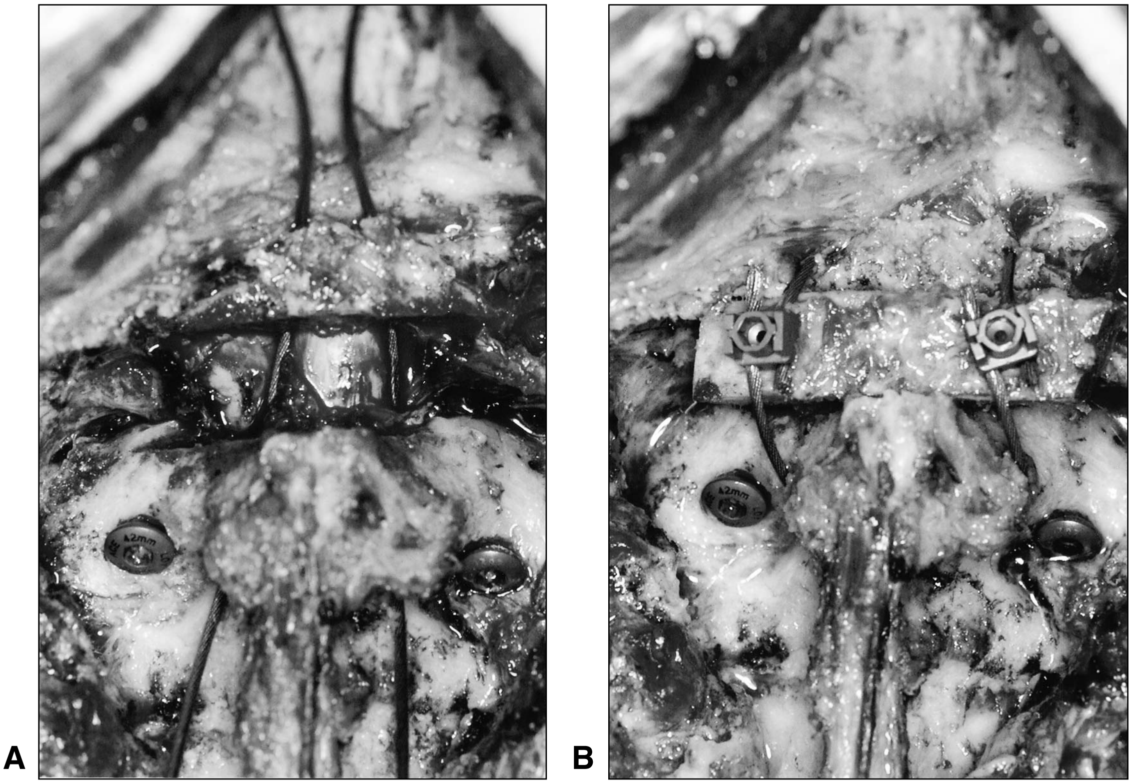

Figure 4: A. *The finished construct after preparation of the graft site and passage of the left and right multistranded cables, before bone graft insertion. Note the parallel contoured inferior surface of C1 and superior surface of C2.* ***B.*** *Completed arthrodesis with graft in place and tensioned cables. Note maintained integrity of the C2-C3 supraspinous and interspinous ligaments.*

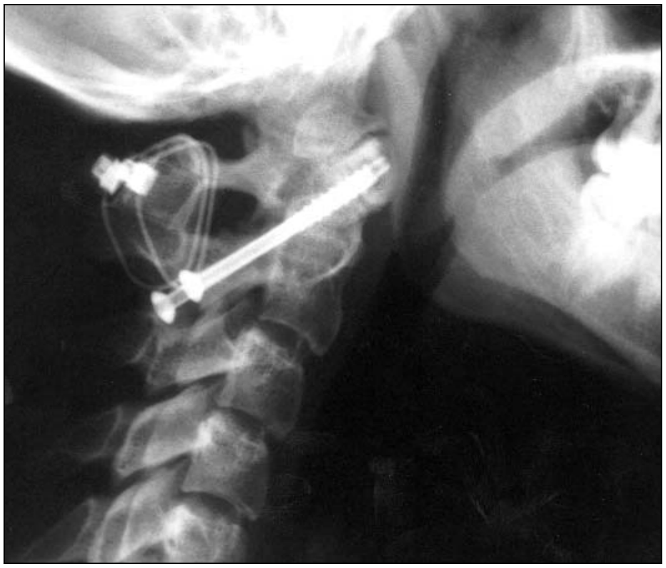

***Figure 5:** Immediate postoperative radiographic study demonstrating transarticular screw placement and the wired bone graft in position between C1 and C2.*

and made popular by Griswold.[10] The Gallie fusion has since been criticized because of instability in translation and rotation, possibly contributing to a relatively high failure rate.[11-13] The Brooks technique, although more stable, was criticized for requiring sublaminar wires beneath both C1 and C2, potentially increasing the possibility of cord injury.[14,15] In 1991, Sonntag described a modification of the Gallie technique to avoid the limitations described above.[3] Briefly, a bicortical graft is wedged between the lamina of C1 and C2 and secured by a sublaminar cable passing under the C1 lamina and trapping the graft by looping around the C2 spinous process and tightening the free cable ends underneath the spinous process of C2, ie. obliquely. As stand-alone procedures, fusion rates of 78-95% are best optimized with rigid postoperative halo fixation.[2] The use of Halifax clamps, although thought to provide stability equal to Brooks wiring,[13] has an unacceptably high failure rate likely due to rotational instability.[4] It has been abandoned by some centres.[2] Magerl introduced the use of transarticular screws to augment C1-C2 arthrodeses.[5] This technique has been used in association with bone graft and wiring to provide three-point fixation and alleviate the need for postoperative Halo immobilization and its complications.[6,16] The procedure requires meticulous attention to detail and thorough review of pre-operative imaging to prevent injury to the vertebral arteries, but provides a more stable construct.[11,17] To avoid vascular complications, some have advocated transarticular screw use only in situations where the potential for fusion failure and neurological injury is high (e.g. os odonteum and traumatic transverse atlantal ligament rupture).[2] Others feel that, in experienced hands, this three-point fixation should be considered the standard of care, with fusion rates approaching 98%, and use this technique in all of their arthrodeses.[6]

This report describes our three-point fixation technique where transarticular screws are used in association with a modification of the Brooks wedge compression and posterior wiring. We feel that this new technique is superior to others for several reasons:

- In contrast to the original Brooks method (one sublaminar wire and one bone graft on each side of midline), and the subsequent Sonntag modification of the Gallie technique (one wire for one graft), the present modification is inherently more stable as a single graft is secured by two independent sublaminar cables.
- Using two cable fixation along the direction of spinal axis reduces tendency for C1-C2 translation while optimizing bone healing under unopposed compression. This provides an advantage over the modified Gallie or Sonntag technique where tightening of the cables occurs in an angle that is oblique to the spinal axis, since the top of the bone graft is flush with C1 but the bottom rides above the lamina of C2.[3] At least theoretically, such an oblique angle is less favorable for bony union. One must also consider the potential that with tightening of the Sonntag cable, C1 tends to be pulled posteriorly on C2.
- In sharp contrast to Brooks' original method, the flat graft contour of this modified technique, using a high speed drill, maximizes the surface area contact between the cancellous bone graft and the native bone under compression at both C1 and C2. In principle this should reduce the incidence of non-union.
- By using sublaminar cables on each side of midline, the interspinous and suprasinous ligaments between C2-3 are preserved, decreasing the propensity for destabilization of the C2-3 motion segment immediately below the fusion construct. In the modified Gallie or Sonntag technique, the cable is looped around the spinous process of C2, typically necessitating the division of these structures.[3]
- In selected cases we have observed a hypoplastic spinous process of C2, or a spinous process with a relatively flat or near-parallel with respect to the spinal canal. These situations are unfavorable to provide firm footing for the inferior end of the bone graft as required with the modified Gallie or Sonntag technique. The modified Brooks method we describe provides for perpendicular contouring within the lamina of C2 and hence does not depend on the profile of the spinous process.
- This modification of the Brooks method may be used in situations where the posterior arch of C1 has congenitally failed to fuse (spina bifida occulta). Since two multistranded cables direct force axially on both left and right sides, a congenital midline defect in C1 can be accommodated. In the modified Gallie or Sonntag technique, cable tensioning converges towards the midline of C2, which in our hands can cause the looped cable to slip through the posterior defect of C1, resulting in construct failure. This technique can also be used in situations where the lamina of C1 is fractured, depending on the type of fracture. For example, while the method is not appropriate if a fracture results in a "floating" posterior C1 ring, it could easily be used if a sagittal fracture through either the anterior or posterior ring is present.

It is acknowledged that the modified Brooks method requires passage of two cables under both C1 and C2, which might be argued to increase the risk of spinal cord injury. We feel that in the absence of high cervical stenosis (evaluated with pre-operative imaging), through the use of modern multistranded cables, and with careful exposure and sublaminar passage, the risk of spinal cord injury is negligible and the gain in construct versatility and stability worthwhile.

CONCLUSIONS

The aforementioned modification of the Brooks posterior wiring for C1-C2 arthrodesis, when supplemented with transarticular screw fixation, provides a stable construct for cervical fusion. The advantages over previously described wiring techniques lie in the axial direction of force directed to the bone graft upon cable tightening promoting bone healing under pure compression, the ability to maintain the anatomical relationship between C1-C2, maximization of cancellous surface area contact, and the preservation of the C2-C3 interspinous and supraspinous ligaments. Furthermore, this modification is clearly superior to other techniques in situations where the spinous process of C2 is hypoplastic or adversely sloped (disallowing firm footing for the graft or improper seating of the cables) and when the posterior arch of C1 is congenitally unfused. We believe the modified Brooks technique can be employed both safely and effectively in almost all conditions requiring posterior C1-C2 instrumented fusion.

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