Review

THE HALO SKELETAL FIXATOR: CURRENT CONCEPTS OF APPLICATION AND MAINTENANCE

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ABSTRACT

The halo device provides the most rigid cervical immobilization of all cervical orthoses. Despite its established efficacy, reported complications include pin loosening (36% to 60%), pin-site infection (20% to 22%), severe pin discomfort (18%), ring migration (13%), pressure sores (4% to 11%), unacceptable scars (9% to 30%), nerve injury (2%), dysphagia (2%), prolonged bleeding at pin sites (1%), and dural puncture (1%). Appreciation of skull anatomy and established application guidelines can help minimize these complications. A relative “safe zone” for anterior pin placement is located 1 cm above the orbital rim, superior to the lateral two thirds of the orbit. This position avoids injury to the nearby frontal sinus (medially), temporalis fossa (laterally), and sensory nerves (supraorbital and supratrochlear nerves medially, and zygomaticotemporal nerve laterally). Posterior pin positions are less critical, located roughly diagonal to the contralateral anterior pins. Pins should enter the skull perpendicular to the cortex, with the ring or crown sitting below the equator of the skull, passing about 1 cm above the helix of the ear. Pins are inserted at 8 in-lbs and re-tightened once at 48 hours. A loose pin can be re-tightened to 8 in-lbs if resistance is met; otherwise, a loose pin requires replacement in a nearby site. Superficially infected pins are managed with oral antibiotics and local pin care. Refractory infections require pin removal, parenteral antibiotics, and incision and drainage as indicated. Dysphagia (difficulty in swallowing), produced by exaggerated cervical extension, may necessitate repositioning of the C-spine. Dural pin puncture is managed with hospitalization, antibiotics, and elevation of the head of the bed to decrease cerebrospinal fluid pressure and allow dural healing. Pressure sores are treated by prevention with well-padded vests/casts and the use of skin precautions, especially in sensory-deprived spinal cord injury patients. Inability to maintain reduction with a halo fixator usually requires open reduction and internal fixation of the cervical spine.

The halo skeletal fixator provides the most rigid type of cervical immobilization of all cervical orthotic devices.1-3 Though there recently has been a trend toward the use of rigid internal fixation, the halo fixator still remains popular and is the method of choice (or reasonable treatment alternative) for immobilization of many types of cervical instabilities.4-14

The original halo was introduced by Perry and Nickel in 1959,33 and since then, its effectiveness in cervical spine stabilization has been well-established.5,6,13,18-20,29,31,32,34,36,39,40,42,44,45

For many years following the introduction of the halo, few modifications were made in the design or methods of application.16,30,31,32,33
Despite its effectiveness, problem areas and potential complications (especially those involving pin loosening and infection) eventually became apparent.\textsuperscript{1,3,10,25,32,39,40-52} Subsequent studies on skull anatomy, biomechanics of pin fixation, and halo pin insertion techniques\textsuperscript{10,25,46,47,49-51,53-60} now provide scientifically based guidelines for halo application and maintenance. As newer materials have become available, the structural components of the device also have changed.\textsuperscript{5,11,25,37,43,46,47,50-58,61,62}

This report summarizes the methods of application and maintenance of the halo device. The discussion has been divided into six areas: development of the original halo, pin-insertion methods, halo/vest application, biomechanical considerations, management of complications, and application of the halo in children.

**Development of the Halo**

A device similar to the current halo, but consisting of an incomplete ring (open posteriorly), was developed by orthopedic surgeon Bloom during World War II (Nickel VL, personal communication, 1992). The device was used to treat pilots who had sustained inwardly displaced facial fractures with overlying skin burns. The device stabilized the fractures with outward-applied traction through pins placed into the facial bones. Traction was applied through an incomplete ring fixed to the skull. The pin design was similar to those used today.

Bloom’s device subsequently led to the development of the renown halo skeletal fixator, conceived by Vernon Nickel, and reported by Perry and Nickel in 1959.\textsuperscript{33} Their original halo consisted of a complete ring that was suspended from above by long rods attached to a body cast. Skeletal pins were placed through holes in the ring to anchor the skull to the ring. The device was actually conceived to accomplish a new operative procedure (total cervical spine fusion for neck paralysis) in patients with poliomyelitis. These patients, with paralytic cervical muscles, were unable to hold their head upright and maintain a patent airway.\textsuperscript{30,31,33} Following the successful use of the halo for cervical arthrodesis, it was subsequently adapted to stabilize the cervical spine following trauma, infection, tumors, inflammatory conditions, degenerative diseases, and in congenital malformations.\textsuperscript{4,31,42-44} (Nickel VL, personal communication, 1992).

It was used successfully in adults and children. The halo became the gold standard for external fixation of the cervical spine.

_Halo Ring or Crown._ The original halo ring was made of metal, had multiple holes for pin insertion, and was available in different sizes. The ring curved upward in the rear to afford greater surgical exposure to the upper cervical spine with the ring in place. (Since the device was developed for cervical fusion, the fixator was placed prior to surgical exposure, and arthrodesis was carried out with the fixator in place.) The halo ring connected to a plaster body jacket by two upright anterior posts.\textsuperscript{33}

Improvements in materials and design have resulted in several different cervical fixators now available from a variety of manufacturers. Lightweight metals and composite materials have led to radiolucent rings, adjustable rings, and convertible long-to-ring devices. More recently, open rings or “crown” type devices that encircle only a part of the head have become popular. The crown designs, which are open posteriorly, avoid the need to pass the head through a ring, thus improving safety and easing application. In some of the crown designs, the posterior ends of the incomplete ring are angled inferiorly to ensure posterior pin placement below the equator of the skull.

_Halo Vest._ Advancements in plastics technology have resulted in the development of lightweight, durable, quickly applied, adjustable vests that have replaced the earlier plaster body casts.\textsuperscript{16,33,60} Cross-straps and supports stabilize the vest’s fit and decrease shear stress between the anterior and posterior portions. A low-profile design for the metal uprights and connecting rods provides a more comfortable frame. Anodizing and/or special coating of the metal upright rods helps prevent metal seizing during tightening. The connecting bolts on the vest can be tightened with torque wrenches that ratchet and give way at a set amount of torque (ie, 28 ft-lbs), thereby saving time and minimizing chances of over-tightening and bolt stripping. Current plastic vests and connecting-rod systems allow cervical spine adjustment in virtually any plane. Safety-knurled adjustment knobs, two-point flexion-extension supports with ratchets, and lightweight metals have allowed fine adjustments for fracture alignment. Some of the vests allow the anterior portion to be moved out of the way of the chest (pivoting at the anterior connection bolts) to permit emergency cardiopulmonary resuscitation while the remainder of the halo/crown and vest remain intact.

Despite advantages of ease of application, the prefabricated vests do not always fit adequately, especially if limited sizes are available. If a vest fits poorly (especially in thin or obese patients), placement of a plaster body cast should be considered. This is particularly true if there are pre-existing skin problems or multiple injuries that require custom fitting to the trunk.

_Halo Pins._ Few changes have been made in
Table 1

DESIRABLE FEATURES OF THE HALO SKELETAL FIXATOR

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tbody>
<tr>
<td>Ring/Crown and Pins</td>
<td>Maximum number of threaded holes structurally possible (to ease pin-site selection)</td>
</tr>
<tr>
<td>Occipital area open</td>
<td>(to ease crown placement)</td>
</tr>
<tr>
<td>Posterior ends of crown angulated inferiorly</td>
<td>to aid posterior pin placement below the equator of the skull</td>
</tr>
<tr>
<td>Radiolucent</td>
<td>MRI compatible (non-ferrous, non-magnetic)</td>
</tr>
<tr>
<td>Pins placed with break-away wrenches set at</td>
<td>8 in/lb</td>
</tr>
<tr>
<td>Easy connections to upright posts</td>
<td>Holes allow pin placement at 90° to skull</td>
</tr>
<tr>
<td>Pins have shoulder</td>
<td></td>
</tr>
<tr>
<td>Upright posts</td>
<td>Low profile with length above ring/crown kept to minimum</td>
</tr>
<tr>
<td>Do not interfere with lateral radiographs</td>
<td>(radiolucent or strategically placed)</td>
</tr>
<tr>
<td>Multiplane adjustment of head and neck</td>
<td>Fine tuning not essential</td>
</tr>
<tr>
<td>Vert</td>
<td>Lightweight, conforming, yet rigid enough to provide support</td>
</tr>
<tr>
<td>Compatible sizes with additional pediatric</td>
<td>Bridges or cross-straps connecting anterior and large sizes available</td>
</tr>
<tr>
<td>and extralarge sizes available</td>
<td>Radioolucent buckles and attachments</td>
</tr>
<tr>
<td>Easy and quick to apply, particularly in an</td>
<td>Provision for emergency access to the anterior chest</td>
</tr>
<tr>
<td>unstable or anesthetized patient</td>
<td></td>
</tr>
</tbody>
</table>

Modified from Botte et al

The halo pin design since its original description. It has been shown, however, that altering this design significantly improves mechanical qualities of the pin-bone interface. A pointed, bullet-type pin with a broad shoulder may provide more rigidity at the pin-bone interface than currently available pins. The design, and others including a peg-type tip with a broad shoulder, are still under investigation and are not commercially available. Titanium pins, which are claimed to be lighter, stronger, and harder than stainless steel, are more difficult and more expensive to manufacture.

“Break-away” torque wrench handles designed for one-time use to insert halo pins have been recently introduced. These wrenches break off at a set amount of torque (e.g., 8 in-lbs = 0.9 Nm), and can potentially save time. They are smaller than standard wrenches and allow pin tightening in cramped situations or when there is limited access to the posterior aspect of the skull, such as when the patient is on a rotating-type bed. Though preliminary results show these wrenches to be accurate, rechecking the pin torque with a calibrated torque screwdriver is prudent. Desirable features of a halo apparatus are listed in Table 1.

PIN INSERTION TECHNIQUES

Pin-Site Selection. The preferred sites for halo pin insertion have been studied in cadaver skulls, radiographs, and clinical reviews of pin-related complications. The optimal position for anterior halo pin placement, based on anatomic structures, is in the anterolateral aspect of the skull, approximately 1 cm superior to the orbital rim (eyebrow), above (cephalad to) the lateral two thirds of the orbit, and below the greatest circumference (equator) of the skull. This area can be considered a relatively “safe zone” (Fig). Placement of the pin above the supraorbital rim prevents displacement or penetration into the orbit. Placement of the pin below the level of the greatest skull diameter helps prevent cephalad migration of the pin.

On the lateral aspect of the safe zone lies the temporalis muscle and fossa, along with the zygomaticotemporal nerve (a small cutaneous nerve that supplies sensibility to the skin in the temple area). Avoidance of the temporalis muscle and fossa is desirable for two reasons: penetration of the temporalis muscle by the halo pin can be painful and may impede mandibular motion during mastication or speaking; and the bone in this area is very thin, often consisting of a single, thin cortical shell without a cancellous component, thus making skull penetration or pin loosening more likely. Injury to the zygomaticotemporal nerve may potentially cause numbness, pain, or paresthesia.

Though placement of anterior halo pins in the
Table 2

<table>
<thead>
<tr>
<th>MATERIALS FOR HALO APPLICATION</th>
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<tbody>
<tr>
<td>Three-person minimum recommended</td>
</tr>
<tr>
<td>Sterile halo ring/crown in pre-selected size</td>
</tr>
<tr>
<td>Sterile halo pins (5, including one spare)</td>
</tr>
<tr>
<td>Halo torque screwdrivers (2) or “break-away” wrenches (4)</td>
</tr>
<tr>
<td>Halo pin locknuts</td>
</tr>
<tr>
<td>Halo vest in pre-selected size</td>
</tr>
<tr>
<td>Halo upright post and connecting rods</td>
</tr>
<tr>
<td>Head board</td>
</tr>
<tr>
<td>Spanners or ratchet wrenches (3)</td>
</tr>
<tr>
<td>Preparation razors (2)</td>
</tr>
<tr>
<td>Povidone-iodine solution</td>
</tr>
<tr>
<td>Sterile gloves (3 pairs)</td>
</tr>
<tr>
<td>Sterile gauze (4 packages of 2, 4 x 4” size)</td>
</tr>
<tr>
<td>Syringes (2, 10 cc)</td>
</tr>
<tr>
<td>Needles (4, 25 guage)</td>
</tr>
<tr>
<td>Lidocaine hydrochloride (10 cc of 1% solution)</td>
</tr>
<tr>
<td>Crash cart (including manual resuscitator, endotracheal tube)</td>
</tr>
</tbody>
</table>

*Modified from Roate et al.*

The temporals region behind the hairline has the advantage of hiding the pin scar, the anatomic and mechanical disadvantages of this site should be considered when choosing it if the other safer areas (as described above) are available.3,5,11,56,59,61

Along the medial aspect of the safe zone lie the supraorbital and supratrochlear nerves and underlying frontal sinus. Placement of the pin lateral to the medial one third of the orbit should avoid injury to these nerves and decrease risks of penetration into the frontal sinus.3,5,11,56,58,61

Placement of the posterior pins is less critical, since vulnerable neuromuscular structures are lacking and the skull is more uniform and thicker in these areas. The posterolateral aspects of the skull at the 4 o’clock and 8 o’clock positions are satisfactory for posterior pin placement (directly anterior = 12 o’clock).3,5,11,56,58,61 Although posterior pin-site locations are less critical, it is desirable to place them approximately diagonal to the corresponding contralateral anterior pins (ie, right posterolateral pin diagonal to left anterolateral pin). The posterior sites should be inferior to the equator of the skull, yet superior enough to prevent ring or crown impingement on the upper helix of the ear. Optimal, the ring or crown will pass approximately 1 cm cephalad to the top of the ear.

Angle of Pin Insertion. The angle of pin insertion can influence pin fixation.60 Cyclic loading of pins inserted at different angles demonstrated that perpendicularly inserted pins have superior fixation to those placed at 15° or 30° to the skull surface. This is presumably due to the broader pin-bone interface with increased contact area achieved with perpendicularly placed pins. With angulation, the shoulder of the pin may intercept the skull’s outer cortex before the tip is fully seated.60 As pin angle is pre-determined by the ring or crown in many current halo devices, placement of the ring or crown over a relatively flat portion of the skull (which is usually below the skull’s widest circumference or “equator”) is desirable to help obtain a perpendicular insertion at the pin-bone interface.

Use of Skin Incisions. Clinical studies comparing use of skin incisions prior to pin placement compared to direct insertion into the skin without an incision indicate no apparent advantages to preplacement of a skin incision.47 Loosening, infection, comfort, and resultant scars were not altered by the use of a small skin incision prior to pin insertion. Skin incisions do, however, take additional time, and may cause bleeding, which momentarily, at least, can delay the halo application procedure. Therefore, routine placement of skin incisions for halo pin placement does not seem warranted.47

Pin-Insertion Torque. The pin-insertion torque originally recommended was 5 to 6 in-lbs (0.57 to 0.68 Nm).19,20,49 These recommendations were based on empirical observations.32 Because of problems with pin loosening, anatomic studies on cadaver human skulls were carried out and demonstrated that halo pins inserted at up to 10 in-lbs (1.13 Nm) barely penetrated the outer table of the skull.46 Mechanical testing of the pin-bone interface (cyclic loading and load-to-failure) indicated that a torque of 8 in-lbs (0.90 Nm) significantly improved the mechanical qualities over those achieved with 6 in-lbs (0.68 Nm).57 Clinically, the use of 8 in-lbs (0.90 Nm) was found to be safe and effective in lowering the incidence of pin loosening and infection when compared with application at 6 in-lbs (0.68 Nm).46 From these studies, 8 in-lbs (0.90 Nm) appears to be preferable to the 5 or 6 in-lbs torque originally recommended.

Method of Halo Application

Preparation and Selection of Equipment. Ring or crown size and vest size are determined, and all materials and equipment are inspected.5,43,61 Suggested materials are listed in Table 2. Positioning pins and mechanical head holders are helpful. Ring or crown size is determined by selection of a ring or crown that provides 1 cm to 2 cm of clearance around every aspect of the head perimeter. Vest size is determined by measurement of chest circumference using a tape measure. A crash cart with resuscitation equipment should be available throughout the procedure.
At least three persons are required for optimal halo application. The person holding the head must be appreciative of the type and nature of the cervical instability, and be comfortably situated while maintaining the position of the unstable cervical spine. This task should not be left to an inexperienced member of the team.

Preparation of the Patient. If medical and neurologic status permit, the patient is lightly sedated, but kept awake to report any changes in neurologic status during head or neck manipulation. General anesthesia is not recommended, unless required for concomitant surgical procedures. If the patient is in traction tongs prior to halo application, a hard collar can be placed before tong removal. The hard collar left in place during halo application procedure provides additional temporary stability and protection of the cervical spinal cord.

The patient in the supine position on the bed or gurney is positioned with the head held beyond the edge. If a crown-type halo is employed (with the posterior portion of the ring open), the patient’s head can remain on the bed. A head-ring support aids application.

Anterior pin sites are selected in the anterolateral aspect of the skull (approximately 1 cm superior to the supraorbital rim, medial to the temporalis muscle and fossa, and cephalad to the lateral two thirds of the orbit). These skin sites for pin insertion will be prepared with a povidone-iodine solution following posterior pin-site preparation (see below).

Posterior pin sites are then selected. As mentioned, these sites are located in the posterolateral aspects of the skull at the approximate positions of 4 o’clock and 8 o’clock (occiput = 6 o’clock), placing the posterior pins approximately diagonal to the corresponding contralateral anterior pins. These pins should also be inferior to the equator of the skull, yet superior enough so that the ring or crown will pass approximately 1 cm cephalad to the upper margin of the ear. The hair is shaved at the posterior pin sites and the skin prepared with povidone-iodine solution.

Application of the Halo Ring or Crown. The ring or crown should be sterile (otherwise pin contamination can occur when the sterile pin is passed through the ring and into the skin). The ring or crown is slipped over the head and held in position below the equator of the skull, but above the top of the ear, as described above. The center hole (if present) in the anterior portion of the ring or crown aids to center the anterior portion. The skin is sterilized and infiltrated with 1% lidocaine hydrochloride solution. If a sterile ring or crown is used, the injection can be placed through the selected hole in the ring or crown. Pins are advanced directly through the skin using a torque screwdriver, inserting the pins as perpendicular to the skull surface as possible. During anterior pin advancement, the patient is asked to gently close the eyes and relax the forehead. This helps prevent skin or eyebrow tenting or tethering, which can hinder eyelid closing after pin insertion. Alternating in a diagonal fashion, the pins are tightened at 2 in-lbs intervals until an 8 in-lb (0.90 Nm) torque is reached. If “one-time break-off” handles are used, the torque should be verified with a calibrated torque screwdriver. The locknuts are placed and gently tightened. Over-tightening of the locknuts is avoided, as this can cause the halo pin to back out. Usually only one eighth of a turn with the spanner is necessary for tightening once the locknut firmly contacts the ring. When the halo is secured, manual traction on the ring or crown can be used to control the cervical spine. Areas of tented skin surrounding the pins are released with a scalpel.

Application of the Vest. With continued manual cervical traction, the patient’s trunk is elevated to allow placement of the posterior half of the vest. The posterior portion of the vest is connected to the ring or crown. The anterior half of the vest is then placed, and the head and neck are positioned and bolts secured. Ratchet-type wrenches that give way at a set torque (ie, 28 ft-lbs) can speed application of the bolts and prevent stripping. The application tools should be kept at the bedside or taped to the vest in case emergency removal of the vest is required. The temporarily-placed Philadelphia collar is then removed. A post-fixation radiograph of the cervical spine is obtained.

Following initial application, the pins are re-tightened once to 8 in-lbs (0.90 Nm) at 48 hours post-application. Dressings are not used routinely around the pin sites. The sites are kept clean with hydrogen peroxide, cleansing with a sterile swab every other day, or as needed.

Table 3 summarizes the steps in halo fixator application.

BIOMECHANICAL ASPECTS

Though the halo is the treatment of choice for many types of cervical spine instabilities, the device has been shown to allow motion and variation of forces across the cervical spine. Motion and force variations are dependent on patient position and activity with the halo in place.

Early studies on motion of the cervical spine with the halo in place demonstrated only 4% of normal motion during flexion and extension movements of the head and neck. Subsequent studies, however, revealed more significant mo-
Table 3

PROCEDURE SUMMARY FOR HALO APPLICATION

1. Determine ring or crown size (hold ring or crown over head, visualize proper fit)
2. Determine vest size (from chest-circumference measurement)
3. Keep patient awake or lightly sedated
4. Identify pin-site locations (while holding ring or crown in place)
5. Shave hair at posterior pin sites
6. Prepare pin sites with povidone-iodine solution
7. Anesthetize skin at pin sites with 1% lidocaine hydrochloride
8. Advance sterile pins to level of skin
9. Have patient gently close eyes
10. Tighten pins at 2 in/lb increments in diagonal fashion
11. Seat and tighten pins to 8 in/lb torque
12. Apply locknuts to pins. Avoid overtightening of locknuts
13. Maintain cervical traction and raise patient trunk to 30°
14. Apply posterior portion of vest
15. Connect posterior portion of vest to ring/crown with uprights
16. Apply anterior portion of vest
17. Connect anterior portion of vest to ring/crown with uprights
18. Recheck fittings, screws, and nuts
19. Tape vest-removing tools to vest or keep at bedside
20. Obtain cervical spine radiographs
21. Re-tighten pins once to 8 in-lbs at 48 hours post-halo application
22. Keep pin sites uncovered, kept clean with hydrogen peroxide maintenance cleansing every other day or as needed

Modified from Botte et al.¹

Table 4

COMPLICATIONS ASSOCIATED WITH USE OF THE HALO

<table>
<thead>
<tr>
<th>Complication</th>
<th>Percentage of Patients</th>
</tr>
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<tbody>
<tr>
<td>Pin loosening</td>
<td>36% to 60%</td>
</tr>
<tr>
<td>Pin-site infection</td>
<td>20% to 22%</td>
</tr>
<tr>
<td>Severe pin discomfort</td>
<td>18%</td>
</tr>
<tr>
<td>Ring migration</td>
<td>13%</td>
</tr>
<tr>
<td>Pressure sores</td>
<td>4% to 11%</td>
</tr>
<tr>
<td>Re-dislocation</td>
<td>10%</td>
</tr>
<tr>
<td>Restricted ventilation from vest</td>
<td>8%</td>
</tr>
<tr>
<td>Restricted arm elevation from vest</td>
<td>23%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>5%</td>
</tr>
<tr>
<td>Nerve injury</td>
<td>2%</td>
</tr>
<tr>
<td>Dysphagia</td>
<td>2%</td>
</tr>
<tr>
<td>Bleeding at pin sites</td>
<td>1%</td>
</tr>
<tr>
<td>Dural puncture</td>
<td>1%</td>
</tr>
<tr>
<td>Neurologic deterioration</td>
<td>1%</td>
</tr>
</tbody>
</table>

From Goffin et al.²³ and Lind et al.²⁷
Modified from Botte et al.¹

When the vest is employed, and over 30 lbs when a cast is employed.⁴⁹ The forces across the cervical spine change due to changes in gravitational forces when the head changes position (i.e., bending over), or with vest distortion from changes in body shape, direct pushing from the lower abdomen, arms or shoulders, or from supporting surfaces. Bending forward from a seated position and reaching sideways while lying significantly changes forces across the cervical spine when the halo is in place. Patients should therefore be cautioned against bending and twisting movements of the trunk while wearing a halo. Medi-lateral forces have been found to be small in comparison with vertical and anteroposterior forces.⁴⁵,⁵¹

MANAGEMENT OF COMPLICATIONS

Despite its effectiveness in immobilizing the cervical spine, substantial complications have been shown to occur.¹³,¹⁰,¹⁴,²⁵,³²,³⁹,⁴⁷,⁵² (Table 4 and 5). Pin loosening and pin-site infection are among the most common problems.¹⁰,²⁵

Loosening. Pin loosening has been shown to occur in 36% to 60% of patients. If a pin becomes loose during the course of treatment (in the absence of infection), the loose pin and remaining pins are re-tightened to 8 in-lbs once, as long as resistance is met within the first few complete rotations of the pin. If no resistance is met, the pin should be removed following placement of a new pin in an adjacent location.¹³,¹⁰,¹¹,⁶¹ Placement of a new pin prior to removal of the loose pin will help maintain ring or crown fixation to the skull during pin change.

Infection. Pin-site infection has occurred in
20% to 22% of patients. If drainage or erythema develops at a pin site, bacterial cultures are obtained, appropriate oral antibiotic therapy is initiated, and local pin care started. If the drainage does not respond to treatment, or if cellulitis or an abscess develops, the pin should be removed following insertion of a new pin at a different site. Incision and drainage are performed as needed, cultures obtained, and parenteral antibiotic therapy instituted.3,5,10,11,81

Pressure Sores. Occurring in 4% to 11% of patients, pressure sores under the halo vest or cast may develop from insufficient cast or vest padding or poorly applied casts. Patients with paralysis and poor protective sensibility who are not appropriately turned, positioned, or mobilized are particularly at risk.10,25 Surgical cervical stabilization with internal fixation may be considered to avoid use of the halo in selected spinal cord injury patients or those with sensibility loss. This minimizes skin problems, and aids in rapid rehabilitation. Pressure sores are best treated by prevention, with appropriate skin protection, cast or vest padding, patient turning and positioning, and frequent skin examination.

Loss of Reduction. Loss of reduction of fractures or dislocations has been shown to occur with the halo in place,25,31,32,49,52 and there has been a trend toward rigid internal fixation of many types of cervical spine instabilities as new instrumentation and techniques have become available. Re-dislocation has occurred in up to 10% of patients. Injuries of the posterior liga-
ments appear to be likely types of cervical spine instabilities that lose reduction.52 Fracture of the superior aspect of the inferior facet has also been associated with loss of reduction with the halo in place. An additional predisposing factor is a poorly fitting vest, especially in large or stout patients where the vest may not be long enough to exert sufficient control on the unstable cervical motion segments.52 Inability to maintain reduction with the halo can be managed, if indicated, with open reduction, internal fixation, and/or arthrodesis of the unstable segments.

Pin-site Bleeding. Pin site bleeding is a rare complication, occurring in 1% of patients. Slow, continuous bleeding at pin sites has been found to occur in patients who are anticoagulated. Tapering the anticoagulant may be required to stop the bleeding. Pin-site packing was ineffective in these cases, as long as anticoagulation medication was continued.5,10

Difficulty in Swallowing. Difficulty in swallowing (dysphagia) was discovered in 2% of patients. This complication can occur if the head and neck are placed in exaggerated extension. Readjustment of the halo to provide less cervical extension (with simultaneous attention given to the cervical pathology) relieves this problem.10

Dural Puncture. Dural puncture is a rare but potentially serious problem. It usually occurs following a blow or a fall onto the halo.3,5,10,11,48,61 Initial symptoms may include headache, malaise, visual disturbances, or other local or systemic symptoms. Clear cerebrospinal fluid leakage around a loose or deeply seated pin should alert one to this possibility. Radiographs may disclose previously unnoticed skull fractures. Special radiographic views tangential or perpendicular to the pin may demonstrate penetration through the inner cortex of the skull.10 Treatment of a dural puncture from a halo pin consists of hospitalization, prophylactic parenteral antibiotics, and pin removal following placement of a new pin at an uninvolved site. Elevation of the head of the bed decreases intracranial cerebrospinal fluid pressure and helps alleviate leakage. The dural tear usually heals in 4 to 5 days. If the leak does not respond, surgical exploration and dural repair may be required. If a subdural abscess develops, surgical incision and drainage are required.10,48

Halo Application in Children

The halo has been used successfully in children and infants for instabilities secondary to injuries or from cervical malformations.15,19,21,28,38,59 In placement of the halo in children, recommended pin-application torques are between 2 and 5 in-lbs.19,28 In children less than 3 years old, a multiple-pin, low-torque technique has been used to allow a greater range of pin-placement sites in areas where the infant skull might be considered too thin or weak to accept limited high-torque forces.28 With the exception of component size and pin torque, halo application for children in this age group requires similar hardware and techniques as used for older patients. Because of the patients' small size, and infrequent use of the halo in this age group, manufacturers may not carry an inventory of parts. Custom-made components may be required.28

Custom fabrication of the halo can be accom-
plished by the following steps, as outlined by Mubarak et al.28: size and configuration of the head is obtained with the use of flexible lead wire placed around the head; the halo ring is fabricated by constructing a ring 2 cm larger in diameter than the wire impression; a plaster mold of the trunk is obtained for manufacture of a custom bivalved polypropylene vest; and linear measurements are made to ensure appropriate length of the superstructure, which is made of lightweight anodized material. A computerized tomography scan helps visualize bone structure to plan pin sites, avoiding suture lines or bone "fragments" (found in congenital malformations).28 Ten to 12 standard halo skull pins can be used. The custom-constructed halo ring is applied under general anesthesia, placing the halo below the skull equator. The pins are inserted to finger or torque tightness of 2 in-lbs circumferentially, avoiding the thinner temporal regions as well as the frontal sinuses areas where thinner cortical bone may be present.28 The vest and superstructure are then applied. The halo pin sites are cleaned daily, or as needed, by the parents. If the pin sites become infected, oral or parenteral antibiotics are started. If drainage persists despite antibiotics, removal of the infected pin is necessary.9,28

The chronology of skull development is relevant in the consideration of potential complications related to halo application in the patient less than 2 years old.28 In this age group, cranial suture interdigitation may be incomplete, and fontanels may be open anteriorly (age less than 18 months) and/or posteriorly (age less than 6 months). Cranial distortion and cranial bone shifting can be minimized by short halo-application periods, custom-fitted halo rings, and evenly distributed, low cranial pressure accomplished through multiple pins.28

CONCLUSION

The halo skeletal fixator, developed by Nickel and Perry, is a proven, effective device for stabilization of many types of cervical instabilities in both adults and children. Despite its effectiveness, complications are numerous, including pin loosening, infection, pin-site bleeding, dysphagia (secondary to exaggerated cervical extension), dural puncture (usually associated with trauma occurring with the halo in place or with concomitant skull fractures), pressure sores, and loss of cervical reduction. Proper application and careful maintenance are necessary to minimize these problems or complications.

REFERENCES