Halo Skeletal Fixation: Techniques of Application and Prevention of Complications

Michael J. Botte, MD, Thomas P. Byrne, OPAC, OTC, Reid A. Abrams, MD, and Steven R. Garfin, MD

Abstract

The halo skeletal fixator provides the most rigid cervical immobilization of all orthoses. However, complications such as pin loosening and infection are common. Appreciation of local anatomy and adherence to established application guidelines should minimize pin-related problems. A relatively safe zone for anterior pin placement is located 1 cm above the orbital rim and superior to the lateral two thirds of the orbit. Posterior pin-site locations are less critical; positioning on the posterolateral aspect of the skull, diagonal to the contralateral anterior pins, is generally desirable. Pins should enter the skull perpendicular to the cortex, with the ring or crown sitting below the widest portion of the skull and passing about 1 cm above the helix of the ear. Pins are inserted at a torque of 8 in-lb and retightened once to 8 in-lb at 48 hours. A loose pin can be retightened to 8 in-lb if resistance is met; otherwise, a loose pin should be replaced at a nearby site. Superficially infected pins are managed with local pin care and oral antibiotics. Persistent or severe infections require pin replacement to a nearby site, parenteral antibiotic therapy, and incision and drainage as needed. Inability to maintain acceptable cervical reduction with a halo fixator is an indication for alternative treatment, such as internal fixation or traction.

J Am Acad Orthop Surg 1996;4:44-53

Since its introduction by Perry and Nickel[1] in 1959, the halo skeletal fixator has been well established as effective and continues to provide the most rigid immobilization of all the cervical orthotic devices.[2] Although there has recently been a trend toward the use of internal fixation, the halo remains popular and is a reasonable treatment alternative for many types of cervical instabilities.[3-36]

Complications of halo skeletal fixation, most notably pin loosening and infection, have been reported.[2,3,6,13,17,24-29] Studies on skull anatomy, biomechanics of pin fixation, and halo-pin insertion techniques have continued, providing more scientifically based guidelines for halo application and maintenance.[3,6,13,24,25,27,28,30-36] Newer materials have become available, and structural components of the device have been improved.[11,13,24,25,31-33,36]

This report summarizes the methods of halo application, with emphasis on the prevention and treatment of associated complications.

Historical Background

A device similar to the current halo, but consisting of an incomplete ring (open posteriorly), was developed by Bloom, an orthopaedic surgeon during World War II. The device was used to treat pilots who had sustained inwardly displaced facial fractures with overlying skin burns. It stabilized the fractures by means of outward traction through pins placed in the facial bones and an incomplete ring fixed to the skull. The pins were similar to those used in the halo today.

Bloom's device subsequently inspired development of the well-known halo skeletal fixator, reported by Perry and Nickel in 1959.[1] The original halo consisted of a complete ring suspended by rods attached to a body cast. The device was used to immobilize the cervical spine for arthrodesis in patients with neck paralysis due to poliomyelitis. Following successful use of the halo

Dr. Botte is Professor of Orthopaedics, University of California, San Diego (UCSD) School of Medicine; and Chief, Rehabilitation Medicine, Veterans Affairs (VA) Medical Center, San Diego. Mr. Byrne is Orthopaedic Physician's Assistant and Orthopaedic Technologist, Department of Orthopaedics, UCSD Medical Center. Dr. Abrams is Assistant Professor of Orthopaedics, UCSD School of Medicine; and Attending Surgeon, Rehabilitation Medicine Service, VA Medical Center, San Diego. Dr. Garfin is Professor of Orthopaedics, UCSD School of Medicine; Chief, Spine Surgery Service, UCSD Medical Center; and Chief, Spine Surgery Service, VA Medical Center, San Diego.

Reprint requests: Dr. Botte, Department of Orthopaedics, University of California, San Diego, 200 West Arbor Drive, 8894, San Diego, CA 92103-8894.

for cervical arthrodesis, the device was subsequently used to stabilize the cervical spine after trauma, as well as in the treatment of infection, tumors, inflammatory conditions, degenerative diseases, and congenital malformations[2-16,22] in both adults and children.[5,14]

Current uses of the halo include stabilization of many Jefferson fractures (C1), certain odontoid fractures (especially type III fractures, which involve the body), most type II hangman's fractures (C2), and single-column cervical spine injuries (primarily bone rather than ligamentous injuries); stabilization for cervical arthrodesis; immobilization of the unstable cervical spine after drainage of infections or tumor resection; and management of cervical fractures in patients with ankylosing spondylitis. The halo can be used to immobilize the spine before, during, and after operative management. Halo traction is also the initial treatment of many unstable ligamentous cervical injuries or burst fractures in the period before surgical stabilization.

Contraindications include concomitant unstable skull fractures and traumatized skin overlying pin sites. The halo fixator, in general, is not optimal as the sole or definitive treatment for cervical instabilities involving ligamentous disruption, two-column injuries, or rotational injuries involving the facet joints. The halo may, however, be used as an adjuvant to operative stabilization to facilitate postoperative rehabilitation and patient mobilization. Although traditionally used for stabilization of cervical vertebrae, the halo may be used in some situations for vertebral instability as far inferior as T1 or T2.

Components of the Halo Fixator

Many improvements have been incorporated in the development of the current ring and crown components. The early halo consisted of a complete ring that was made of steel, had several holes for pin insertion, and was available in different sizes. The ring curved upward in the rear to allow surgical exposure of the upper cervical spine with the ring in place. The halo ring was connected to a plaster body jacket by two upright anterior posts.[17]

Subsequent improvements in materials and design have resulted in different types of rings that are now commercially available (Fig. 1). The development of lightweight metals and composite materials led to the design of radiolucent rings that are compatible with magnetic resonance (MR) imaging, as well as adjustable rings and convertible tongs-to-ring devices. More recently, open rings and crown-type devices that encircle only a part of the head have also been developed. The crown designs, which are open posteriorly, avoid the need to pass the head through a ring and thus ease application and improve safety. With some of the crown designs, the posterior ends of the incomplete ring are angled inferiorly to ensure posterior pin placement below the equator (area of greatest circumference) of the skull.

The halo vest and connecting rods have also undergone structural and design improvements. Advancements in plastics technology have allowed the development of lightweight, durable, easily applied adjustable vests, which have replaced the earlier plaster body casts.[1,35] Cross-straps and supports stabilize the vest and decrease shear stress between the anterior and posterior portions. A low-profile design for the metal uprights and connecting rods has proved more comfortable. Anodizing the metal uprights helps prevent metal seizing during tightening. Lightweight, radiolucent carbon-fiber connecting rods that are MR imaging–compatible have been incorporated. Connecting bolts on the vest can be tightened with torque wrenches that ratchet and give way at a set amount of torque (28 ft-lb), thereby saving time and minimizing the chance of overtightening.

Current plastic vests and connecting-rod systems allow cervical spine adjustment in multiple planes. Safety-knurled adjustment knobs, two-point flexion-extension supports with ratchets, and lightweight metals allow fine adjustments for spine alignment. Some

Fig. 1 **Top,** Standard complete-ring design, similar to original halo. Stainless-steel ring is curved upward posteriorly to allow cervical access during surgery. **Lower left,** Incomplete ring, made of lightweight anodized aluminum, is open posteriorly, with the ends curved downward so that pins insert below widest circumference of skull. **Lower right,** Incomplete ring is open posteriorly to aid application. Carbon-fiber composition is compatible with MR imaging.

vests allow the front portion to be moved away from the chest (pivoting at the anterior connection bolts) to permit emergency cardiopulmonary resuscitation while the remainder of the halo and vest remains intact. Prefabricated vests are easier to apply, but they do not always fit adequately, especially on thin or obese patients. A plaster body cast may be indicated in these cases.

Although improvements have been made in the ring and vests, relatively few changes have been made in the halo pins. Altering the original design, however, may significantly improve the mechanical qualities of the pin-bone interface.[32] Designs still under investigation include a pointed bullet-type pin and a peg-type tip with a broad shoulder, which may provide more rigidity at the pin-bone interface than is possible with currently available pins. Pins made of titanium, which is allegedly lighter, stronger, and harder than stainless steel, are more difficult and more expensive to manufacture (Fig. 2).

Breakaway torque wrenches designed for one-time use to insert halo pins have recently been introduced. These wrenches break off at a set amount of torque (8 in-lb, or 0.90 newton-meter [N·m]), thereby saving time. They are smaller than standard wrenches and allow pin tightening in cramped situations and when there is limited access to the posterior aspect of the skull (such as when the patient is on a rotating bed). Although preliminary results show these wrenches to be accurate, rechecking the pin torque with a calibrated-torque screwdriver is probably warranted. Desirable features of a halo apparatus are listed in Table 1.

Pin-Insertion Techniques

Selection of Sites

Preferred sites for halo-pin insertion have been established from clinical series and anatomic studies.[6,13,25,26,31,33] The optimal position for placement of anterior halo pins is the anterolateral aspect of the skull, approximately 1 cm superior to the orbital rim, cephalad to the lateral two thirds of the orbit, and below the greatest circumference of the skull. This area can be considered a relatively safe zone (Fig. 3). 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 minimizes the tendency toward cephalad pin migration.[3,31,33]

On the lateral aspect of the "safe zone" lie the temporalis muscle and the zygomaticotemporal nerve (the small cutaneous nerve that supplies sensibility to the skin in the temple area). Avoidance of the temporalis muscle is desirable for two reasons: (1) penetration of the muscle by the halo pin is painful and impedes mandibular motion, and (2) the bone in this area is thin, often consisting of a single cortical shell without a cancellous component, which increases the risk of skull penetration or pin loosening. Injury to the zygomaticotemporal nerve may cause numbness, pain, or paresthesias in the temporal region.

Placement of anterior halo pins in the temporalis region behind the hairline has the advantage of hiding the pin scar. However, the anatomic and mechanical disadvantages of this site should be considered when choosing this location over the other, potentially safer areas previously described.[3,31,33]

Along the medial aspect of the safe zone lie the supraorbital and supratrochlear nerves and the underlying frontal sinus. Placement of the pin lateral to the medial third of the orbit should avoid injury to these nerves and decrease the risk of penetration into the frontal sinus.[3,31,33]

The insertion sites of the posterior pins are less critical, since neuromuscular structures are lacking and the skull is thicker and more uniform in that area. If directly anterior on the skull is defined as the 12-o'clock position and directly poste-

Fig. 2 Various pin designs. On the far left is a Gardner-Wells–type halo pin, with a built-in pressure-sensing device to signal adequate insertion pressure. The two central pins are standard, commercially available halo pins with a broad shoulder. These pins are made of anodized stainless steel. The pin on the far right is an experimental design with a peg-type tip. Preliminary studies show this pin, which is not yet commercially available, and others to have potentially improved biomechanical properties for skull fixation.

Table 1
Desirable Features of the Halo Skeletal Fixator*

Ring/crown and pins
Ring/crown contains maximum number of threaded holes structurally possible (to ease pin-site selection)
Occipital area open (to ease crown placement)
Posterior ends of crown angled inferiorly to aid posterior pin placement below equator of skull
Radiolucent
Compatible with MR imaging (nonferrous, nonmagnetic)
Pins placed with breakaway wrenches set at 8 in-lb
Easy connections of ring/crown to upright posts
Holes allow pin placement at 90 degrees to skull
Pins have shoulder
Upright posts
Low profile with length above ring/crown kept to minimum
Radiolucent or strategically placed (so as not to interfere with lateral radiographs)
Adjustable in multiple planes to position head and neck
Fine-tuning not essential
Vest
Lightweight, conforming, yet rigid enough to provide support
Available in wide range of sizes, including pediatric and extra-large
Contains bridges or cross-straps connecting anterior and posterior components to prevent shear motion
Radiolucent buckles and attachments
Designed for easy, quick application, particularly in an unstable or anesthetized patient
Provision for emergency access to the anterior chest

*Adapted with permission from Botte MJ, Garfin SR, Byrne TP, et al: The halo skeletal fixator: Principles of application and maintenance. *Clin Orthop* 1989;239:12-18.

rior is defined as the 6-o'clock position, the posterolateral aspects of the skull at the 8-o'clock and 4-o'clock positions are satisfactory for posterior pin placement.[3,31,33] It is desirable to place the posterior pins roughly diagonal to the corresponding contralateral anterior pins. The posterior sites should be inferior to the widest portion of the skull, yet superior enough to prevent ring or crown impingement on the upper helix of the ear. Optimally, the ring or crown will pass about 1 cm cephalad to the top of the ear.

Angle of Pin Insertion

The angle of pin insertion influences pin fixation.[35] Cyclic loading of pins inserted at different angles has demonstrated that perpendicular insertion is superior to placement at 15 or 30 degrees to the skull surface. This is presumably due to the broader pin-bone interface and the increased contact area achieved with perpendicular placement. With angled pin insertion, the shoulder of the pin may intercept the outer cortex of the skull before the tip is fully seated.[35]

Use of Skin Incisions

Clinical studies indicate no advantage to the placement of skin incisions at pin-insertion sites.[25] The incidence of loosening, infection, and scarring and the patient's comfort level were not altered by the use of a small incision before pin insertion. Skin incisions do, however, take additional time and may cause bleeding, which, momentarily at least, delays the halo-application procedure. Therefore, routine placement of skin incisions for halo-pin placement does not seem warranted.[25]

Pin-Insertion Torque

The original recommendation for pin-insertion torque, based on empirical observations, was 5 to 6 in-lb (0.57 to 0.68 N·m).[10,27] Subsequent studies on cadaver skulls have demonstrated that pins inserted at up to 10 in-lb (1.13 N·m) barely penetrate the outer cortex.[24] Mechanical testing of the pin-bone interface (cyclic loading and load to failure) has shown that a torque of 8 in-lb (0.90 N·m) significantly improves the mechanical qualities compared with a torque of 6 in-lb (0.68 N·m).[32] Clinically, a torque of 8 in-lb (0.90 N·m) has been found safe and effective in lowering the incidence of pin loosening and infection compared with application at 6 in-lb and therefore is preferred for the insertion of halo pins in adults.[24]

Method of Halo Application

Equipment Selection and Preparation

Ring/crown size and vest size are determined and equipment and materials are inspected before initiating the procedure.[3] Suggested items are listed in Table 2. A crash cart with resuscitation equipment should be available throughout the procedure.

Positioning pins and mechanical head holders ease application. The ring or crown selected should provide 1 to 2 cm of clearance around every aspect of the perimeter of the head. Vest size is determined by

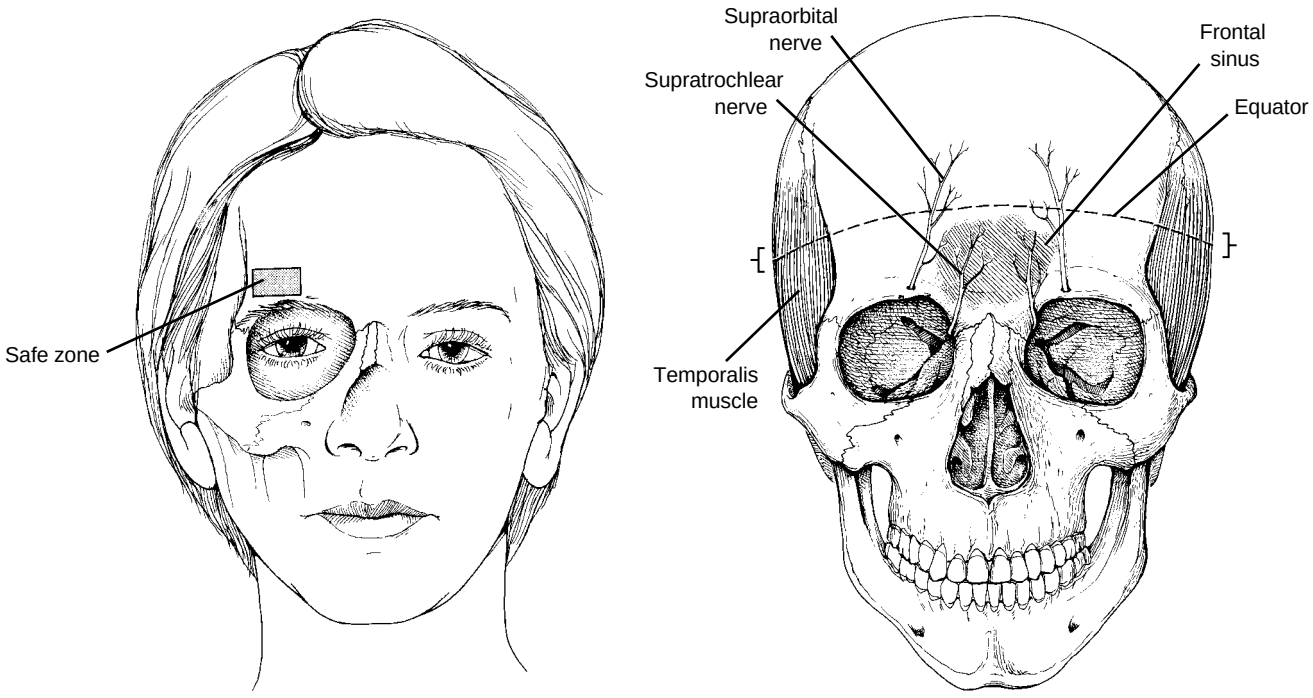

Fig. 3 Left, Drawing depicts the "safe zone" for placement of halo-fixator pins. Anterior pins are placed anterolaterally, approximately 1 cm above the orbital rim, below the equator (area of widest circumference) of the skull, and cephalad to the lateral two thirds of the orbit. **Right,** The safe zone avoids the temporalis muscle and fossa laterally and the supraorbital and supratrochlear nerves and the frontal sinus medially. Posterior pin placement is much less critical because of the lack of neuromuscular structures and the uniformity and thickness of the skull in that area.

measuring the chest circumference at the xiphoid process with a tape measure.

A three-person team is optimal for halo application.[3] The person holding the head should be experienced and appreciative of the type and nature of the cervical instability and should be comfortably situated while maintaining the head and the unstable cervical spine in position.

Patient Preparation

If the patient's medical and neurologic status permit, light sedation may be used, but the patient should be kept awake to report any changes in neurologic status during the procedure. General anesthesia is usually not needed, unless required for concomitant surgical procedures. If traction tongs were applied before halo application, a hard collar can be placed before removal of the tongs. The hard collar left in place during halo application provides additional interim stability and protection of the spinal cord.

The patient is placed supine on the bed or gurney and 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 is helpful.[3]

Anterior pin sites are selected on the anterolateral aspect of the skull. These skin sites should be prepared with a povidone-iodine solution after posterior pin-site preparation.

Posterior pin sites are selected on the posterolateral aspects of the skull. The hair is shaved, and the skin is prepared with povidone-iodine solution.[3]

Application of the Halo Ring or Crown

The ring or crown should be sterile; otherwise, pin contamination occurs when the sterile pin is passed through the ring and into the skin. The ring or crown is slipped over the head and is held in position below the widest portion of the skull but above the top of the ear. The center hole (if present) in the anterior portion of the ring or crown is used as an aid in centering the anterior portion.

The skin is prepared in a sterile fashion, and 1% lidocaine hydrochloride solution is infiltrated. With a sterile ring or crown, the needle for injection can be passed through the selected hole in the ring or crown. Pins are advanced directly through the skin with a torque screwdriver and inserted 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 minimizes skin or eyebrow tenting or tethering, which hinders eyelid closing after pin insertion. Pins are tightened in increments of 2 in-lb, alternating in a diagonal fashion, until a torque of 8 in-lb is reached.[24] If breakaway wrenches are used, the torque should be verified with a calibrated-torque screwdriver. The locknuts are placed and gently tightened. Overtightening the locknuts should be avoided, as this can cause the halo pin to back out. Usually, only an eighth of a turn with the spanner is necessary for tightening once the locknut is firmly in contact with 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 can be released with a scalpel as needed.

Table 2
Equipment and Materials for Halo Application*

Minimum three-person team recommended
Sterile halo ring / crown in preselected size
Sterile halo pins (4, plus 1 spare)
Halo torque screwdrivers (2) or breakaway wrenches (4)
Halo-pin locknuts (4, plus 1 spare)
Halo vest in preselected size
Halo upright post and connecting rods
Head board
Spanners or ratchet wrenches (3)
Preparation razors (2)
Povidone-iodine solution
Sterile gloves (3 pairs)
Sterile gauze, 4x4" (4 packs of 2)
Syringes, 10-mL (2)
Needles, 25-gauge (4)
Lidocaine hydrochloride, 1% solution (10 mL)
Crash cart, including manual resuscitator and endotracheal tube

*Adapted with permission from Botte MJ, Garfin SR, Byrne TP, et al: The halo skeletal fixator: Principles of application and maintenance. *Clin Orthop* 1989;239:12-18.

Application of the Vest

The cervical spine is protected with gently applied manual traction or head positioning. The patient's trunk is elevated about 30 degrees for vest placement. The posterior portion of the vest is connected to the ring or crown, followed by placement of the anterior half of the vest. Alternatively, the patient can be logrolled to apply the vest, although maintaining cervical alignment is more difficult. In the rare cases in which the cervical spine is stable, the vest can be applied with the patient sitting. After vest application, the head and neck are positioned and the bolts are secured. The use of ratchet-type wrenches that give way at a set torque (28 ft-lb) speeds application of the bolts and prevents stripping. The application tools are maintained at the patient's bedside or taped to the vest in case emergency removal of the vest is required.

A postfixation radiograph of the cervical spine is obtained. Fine adjustments of cervical reduction are performed by positioning the head in further extension, flexion, translation, or distraction, depending on the type of injury and the findings on the initial postreduction radiographs. Radiography is repeated after cervical manipulation.

Forty-eight hours after initial application, the pins are retightened once to 8 in-lb. Pin-site dressings are not routinely used. Every other day or as needed, the sites are cleansed with dilute hydrogen peroxide on a sterile swab.

Table 3 summarizes the steps in halo-fixator application.

Biomechanical Considerations

Although the halo is the most stable orthosis for cervical spine immobilization, it has been shown to allow motion and variation of forces across the spine. Motion and force variations are dependent on patient position and activity with the halo in place, as well as the degree of spinal instability.

Initial cervical motion studies with the halo in place demonstrated only 4% of normal motion during flexion and extension.[3] Subsequent studies, however, revealed more significant motion, especially when a patient moved from an upright to a supine position.[27] The greatest absolute amount of motion was seen at the C4-C5 level (7.2 degrees). The greatest percentage of normal motion occurred at the C2-C3 level (42% of normal), and the least amount of motion occurred at the C7-T1 level (20% of normal). The mean overall amount of motion in the cervical spine was 31% of normal.[27] Recently, a mean maximal cervical motion of 51 degrees in the sagittal plane (approximately 70% of normal) was demonstrated with the halo in place. The most restricted motion was below C2, and the least restricted was above C2.[28]

Although the halo was designed to provide distraction across the cervical spine, a number of factors affect the actual forces applied. Both distraction and compression forces across the neck have been demonstrated, as noted by studies that measure forces with strain gauges placed in the vertical rods.[23,27,28] The average distraction force can vary in different positions by nearly 20 lb when a vest is employed and by over 30 lb when a cast is used.[27] The forces across the cervical spine

Table 3
Procedure for Halo Application*

1. Determine ring/crown size (hold ring/crown over head and visualize proper fit).
2. Determine vest size (from chest circumference measurement).
3. Identify pin-site locations while holding ring/crown in place.
4. Shave hair at posterior pin sites and prepare skin with povidone-iodine solution.
5. Anesthetize skin at pin sites with 1% lidocaine hydrochloride.
6. Advance sterile pins to level of skin. Have patient gently close eyes.
7. Tighten pins at increments of 2 in-lb in diagonal fashion. Seat pins at 8 in-lb of torque.
8. Apply locknuts to pins. Avoid overtightening.
9. Maintain cervical reduction and raise patient's trunk to 30 degrees.
10. Apply posterior portion of vest and connect to ring/crown with uprights.
11. Apply anterior portion of vest and connect to ring/crown with uprights.
12. Recheck fittings, screws, and nuts.
13. Tape tools to vest or keep at bedside (for emergency vest removal).
14. Obtain cervical spine radiographs.
15. Retighten pins once to 8 in-lb 48 hours after halo application.
16. Keep pin sites uncovered. Cleanse with hydrogen peroxide every other day or as needed.

*Adapted with permission from Botte MJ, Garfin SR, Byrne TP, et al: The halo skeletal fixator: Principles of application and maintenance. *Clin Orthop* 1989;239:12-18.

change with alterations in gravitational forces when the head is repositioned (e.g., during bending over); with vest distortion due to changes in body shape, direct pushing from the lower abdomen, or movement of the arms or shoulders; and with alterations of the supporting surface. Bending forward from a seated position or reaching sideways while lying down significantly alters forces across the cervical spine with the halo in place. Patients should therefore be cautioned against bending and twisting movements of the trunk. Medial-lateral forces have been found to be small in comparison with vertical and anterior-posterior forces.[23,28]

Complications

Despite the effectiveness of halo skeletal fixation in cervical spine immobilization, complications are common (Table 4).[6,8,13,17,25,29] Pin loosening and pin-site infection are among the most frequent.[6,13]

Pin and Ring/Crown Loosening

Pin loosening has been shown to occur in 36% to 60% of patients.[6,13] If a pin becomes loose in the absence of infection, the loose pin and remaining pins can be retightened once to 8 in-lb 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 after placement of a new pin in an adjacent location.[6] Placement of a new pin before removal of the loose pin will help maintain ring/crown fixation during pin change. Dislodgment of the entire halo is usually the result of a fall.[6] Failure of the halo at the rod-ring or rod-vest interface is rare.

Infection

Pin-site infection has been reported to occur in 20% to 22% of patients.[6,13] If drainage or erythema develops at a pin site, the appropriate course is to obtain bacterial cultures, initiate oral antibiotic therapy, and start local pin care. If the drainage does not respond to treatment or if cellulitis or an abscess develops, the pin should be removed after insertion of a new pin at a different site. Incision and drainage should be performed as needed; cultures should then be obtained, and parenteral antibiotic therapy should be instituted.[6]

Pressure Sores

Pressure sores under the halo vest or cast have been reported to occur in 4% to 11% of patients. Sores may develop because of insufficient padding, use of a vest of inappropriate size, or poor cast application. Patients with paralysis and poor protective sensibility require frequent turning, positioning, and skin inspection.[6,13] Cervical stabilization with internal fixation should be considered in selected patients with spinal cord injuries and in those with preexisting skin disorders, sensibility loss, or overlying burns. Pressure sores are best treated by prevention, with appropriate skin protection and vest padding.

Loss of Reduction

Loss of cervical reduction can occur with the halo in place.[13,16,17,27,29] Redislocation has occurred in up to 10% of patients. Injuries to the posterior ligaments and fractures of the superior aspect of the inferior facet are likely to result in loss of reduction.[29] The use of poorly fitting vests, especially on large or obese patients, on whom the vest may not be long enough to exert sufficient control on the unstable cervical spine, also contributes to loss of reduction.[29] Inability to maintain re-

duction with the halo may require operative stabilization. In the nonoperative patient, a form-fitting cast may be a reasonable alternative if a vest cannot be adequately fitted.

Pin-Site Bleeding

Pin-site bleeding is a rare complication, occurring in only 1% of patients. It is more apt to occur in those who have received anticoagulation therapy. Slow, continuous bleeding at pin sites in these patients may require tapering the anticoagulants. Pin-site packing has been shown to be ineffective if anticoagulation therapy is continued.[3,6]

Difficulty in Swallowing

Dysphagia has been noted in 2% of patients. This complication occurs if the head and neck are placed in exaggerated extension. Repositioning the halo with less cervical extension may relieve the problem if this can be performed without compromising the cervical reduction.[6]

Dural Puncture

Dural puncture is a rare but potentially serious problem. It usually occurs after significant trauma to the halo, such as might result from a blow or a fall onto the device.[3,6,26] Initial symptoms of dural puncture include headache, malaise, visual disturbances, and other local or systemic symptoms. Leakage of clear cerebrospinal fluid around a loose or deeply seated pin should alert one to this possibility. Radiographs may disclose previously unnoticed skull fractures. Special tangential radiographic views, such as those obtained perpendicular to the pin, may demonstrate pin penetration through the inner cortex of the skull.[6]

Treatment of a dural puncture from a halo pin consists of hospitalization, prophylactic parenteral antibiotics, and pin removal after placement of a new pin at a noninvolved site. Elevation of the head of the bed decreases intracranial 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 indicated.[6,26]

Despite proper use of the halo, many residual problems have been reported after halo removal, including residual neck pain or stiffness (80%),[13] decreased cervical rotation (18%)[13] or lateral bending capability (18%),[13] and suboptimal scar healing (9% to 30%).[6,13]

Table 4
Complications Associated With Use of the Halo

Complication	Percentage of Patients
Residual neck pain or stiffness	80%*
Pin loosening	36%-60%*†
Pin-site infection	20%-22%*†
Severe scars	9%-30%*†
Restricted arm elevation from vest	23%*
Severe pin discomfort	18%†
Ring migration	13%*†
Pressure sores	4%-11%*†
Redislocation	10%*
Restricted ventilation from vest	8%*
Pneumonia	5%*
Nerve injury	2%†
Dysphagia	2%†
Bleeding at pin sites	1%†
Dural puncture	1%†
Neurologic deterioration	1%*

*Data reported in Lind B, Sihlbom H, Nordwall A: Halo-vest treatment of unstable traumatic cervical spine injuries. *Spine* 1988;13:425-432.
†Data reported in Garfin SR, Botte MJ, Waters RL, et al: Complications in the use of the halo fixation device. *J Bone Joint Surg Am* 1986;68:320-325.

Halo Application in Children

Halo skeletal fixation has proved successful in children and infants with cervical instability due to injuries or malformations.[10,14,20,34] The recommended pin-application torque is between 2 and 5 in-lb.[10,14] In infants 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 child's skull is too thin or weak to accept limited high-torque forces.[14]

The technique of halo application in this age group is similar to that used in older patients except for differences in component size and pin torque. Because of the infrequent need for the halo in this age group, a full inventory of parts may not be readily available, and custom-made components might be required. Custom fabrication of the halo can be accomplished by the following steps: (1) The size and configuration of the head are obtained

with the use of a flexible lead wire placed around the head. (2) The halo ring is fabricated by construction of a ring 2 cm larger in diameter than the wire impression. (3) A plaster mold of the trunk is obtained for manufacture of a bivalve polypropylene vest. (4) Linear measurements are made to ensure appropriate length of the superstructure, which is made of lightweight anodized material.[14]

Computed tomography can be useful in planning pin sites; bone structure can be visualized so as to avoid suture lines and bone "fragments" (found in congenital malformations). Ten to 12 standard halo skull pins can be used. The custom-constructed halo ring is applied with the patient under general anesthesia. The halo should be placed below the widest diameter of the skull. The pins are inserted to a tightness of 2 in-lb circumferentially, avoiding the temporal regions and the frontal sinus areas, where thinner cortical bone may be present.[33] The vest and superstructure are then applied. Pin care is similar to that for adults.[3,6,14]

Consideration of the chronology of skull development is necessary in the patient aged less than 2 years. In this age group, cranial suture interdigitation may be incomplete, and fontanels may be open anteriorly (in children aged less than 18 months) or posteriorly (in children aged less than 6 months). Cranial distortion and bone shifting can be minimized by using short halo application periods and custom-fitted halo rings and by applying evenly distributed low cranial pressure through multiple pins.[14]

Summary

Halo skeletal fixation has proved effective for stabilization of many types of cervical instability in both adults and children. Improvements in design, materials, and application methods have been instituted recently. However, complications remain prevalent, including pin loosening, infection, pin-site bleeding, dysphagia, dural puncture, pressure sores, and loss of cervical reduction. Proper application and careful maintenance help minimize these problems. Inability to maintain acceptable cervical reduction with a halo fixator may necessitate alternative treatment, such as traction or internal fixation. Use of the halo in children is effective but requires modified equipment and application methods.

References

1. Perry J, Nickel VL: Total cervical-spine fusion for neck paralysis. *J Bone Joint Surg Am* 1959;41:37-60.
2. Johnson RM, Hart DL, Simmons EF, et al: Cervical orthoses: A study comparing their effectiveness in restricting cervical motion in normal subjects. *J Bone Joint Surg Am* 1977;59:332-339.
3. Botte MJ, Garfin SR, Byrne TP, et al: The halo skeletal fixator: Principles of application and maintenance. *Clin Orthop* 1989;239:12-18.
4. Cooper PR, Maravilla KR, Sklar FH, et al: Halo immobilization of cervical spine fractures: Indications and results. *J Neurosurg* 1979;50:603-610.
5. Ewald FC: Fracture of the odontoid process in a seventeen-month-old infant treated with a halo: A case report and discussion of the injury under the age of three. *J Bone Joint Surg Am* 1971;53:1636-1640.
6. Garfin SR, Botte MJ, Waters RL, et al: Complications in the use of the halo fixation device. *J Bone Joint Surg Am* 1986;68:320-325.
7. Garrett AL, Perry J, Nickel VL: Stabilization of the collapsing spine. *J Bone Joint Surg Am* 1961;43:474-484.
8. Glaser JA, Whitehill R, Stamp WG, et al: Complications associated with the halo-vest: A review of 245 cases. *J Neurosurg* 1986;65:762-769.
9. Kalamchi A, Yau AC, O'Brien JP, et al: Halo-pelvic distraction apparatus: An analysis of one hundred and fifty consecutive patients. *J Bone Joint Surg Am* 1976;58:1119-1125.
10. Kopits SE, Steingass MH: Experience with the "halo cast" in small children. *Surg Clin North Am* 1970;50: 935-943.
11. Levine AM, Edwards CC: Fractures of the atlas. *J Bone Joint Surg Am* 1991;73: 680-691.
12. Lind B, Nordwall A, Sihlbom H: Odontoid fractures treated with halo-vest. *Spine* 1987;12:173-177.
13. Lind B, Sihlbom H, Nordwall A: Halo-vest treatment of unstable traumatic cervical spine injuries. *Spine* 1988;13: 425-432.
14. Mubarak SJ, Camp JF, Vuletich W, et al: Halo application in the infant. *J Pediatr Orthop* 1989;9:612-614.
15. Nickel VL, Perry J, Garrett AL, et al: The halo: A spinal skeletal traction fixation device. *J Bone Joint Surg Am* 1968;50: 1400-1409.
16. Nickel VL, Perry J, Garrett AL, et al: Application of the halo. *Orthop Prosthet Appliance J* 1960;14:31-35.
17. Perry J: The halo in spinal abnormalities: Practical factors and avoidance of complications. *Orthop Clin North Am* 1972;3:69-80.
18. Pieron AP, Welply WR: Halo traction. *J Bone Joint Surg Br* 1970;52:119-123.
19. Prolo DJ, Runnels JB, Jameson RM: The injured cervical spine: Immediate and long-term immobilization with the halo. *JAMA* 1973;224:591-594.
20. Sherk HH, Nicholson JT, Chung SM: Fractures of the odontoid process in young children. *J Bone Joint Surg Am* 1978;60:921-924.
21. Thompson H: The "halo" traction apparatus: A method of external splinting of the cervical spine after injury. *J Bone Joint Surg Br* 1962;44:655-661.
22. White R: Halo traction apparatus [abstract]. *J Bone Joint Surg Br* 1966;48:592.
23. Walker PS, Lamser D, Hussey RW, et al: Forces in the halo-vest apparatus. *Spine* 1984;9:773-777.
24. Botte MJ, Byrne TP, Garfin SR: Application of the halo device for immobilization of the cervical spine utilizing an increased torque pressure. *J Bone Joint Surg Am* 1987;69: 750-752.
25. Botte MJ, Byrne TP, Garfin SR: Use of skin incisions in the application of halo

skeletal fixator pins. *Clin Orthop* 1989;246:100-101.
26. Garfin SR, Botte MJ, Triggs KJ, et al: Subdural abscess associated with halo-pin traction. *J Bone Joint Surg Am* 1988;70:1338-1340.
27. Koch RA, Nickel VL: The halo vest: An evaluation of motion and forces across the neck. *Spine* 1978;3:103-107.
28. Lind B, Sihlbom H, Nordwall A: Forces and motions across the neck in patients treated with halo-vest. *Spine* 1988;13: 162-167.
29. Whitehill R, Richman JA, Glaser JA: Failure of immobilization of the cervical spine by the halo vest: A report of five cases. *J Bone Joint Surg Am* 1986;68:326-332.
30. Ballock RT, Lee TQ, Triggs KJ, et al: The effect of pin location on the rigidity of the halo pin-bone interface. *Neurosurgery* 1990;26:238-241.
31. Garfin SR, Botte MJ, Centeno RS, et al: Osteology of the skull as it affects halo pin placement. *Spine* 1985;10:696-698.
32. Garfin SR, Lee TQ, Roux RD, et al: Structural behavior of the halo orthosis pin-bone interface: Biomechanical evaluation of standard and newly designed stainless steel halo fixation pins. *Spine* 1986;11:977-981.
33. Garfin SR, Roux R, Botte MJ, et al: Skull osteology as it affects halo pin placement in children. *J Pediatr Orthop* 1986;6:434-436.
34. Letts M, Kaylor D, Gouw G: A biomechanical analysis of halo fixation in children. *J Bone Joint Surg Br* 1988;70: 277-279.
35. Triggs KJ, Ballock RT, Lee TQ, et al: The effect of angled insertion on halo pin fixation. *Spine* 1989;14:781-783.
36. Botte MJ, Byrne TP, Abrams RA, et al: Avoiding pitfalls in halo applications. *Operative Techniques Orthop* 1993;3:257-267.