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Occipitocervicothoracic fixation for spinal instability in patients with neoplastic processes

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Object. Occipitocervicothoracic (OCT) fixation and fusion is an infrequently performed procedure to treat patients with severe spinal instability. Only three cases have been reported in the literature. The authors have retrospectively reviewed their experience with performing OCT fixation in patients with neoplastic processes, paying particular attention to method, pain relief, and neurological status.

Methods. From July 1994 through July 1998, 13 of 552 patients who underwent a total of 722 spinal operations at the M. D. Anderson Cancer Center have required OCT fixation for spinal instability caused by neoplastic processes (12 of 13 patients) or rheumatoid arthritis (one of 13 patients). Fixation was achieved by attaching two intraoperatively contoured titanium rods to the occiput via burr holes and Luque wires or cables; to the cervical spinous processes with Wisconsin wires; and to the thoracic spine with a combination of transverse process and pedicle hooks. Crosslinks were used to attain additional stability. In all patients but one arthrodesis was performed using allograft.

At a follow-up duration of 1 to 45 months (mean 14 months), six of the 12 patients with neoplasms remained alive, whereas the other six patients had died of malignant primary disease. There were no deaths related to the surgical procedure. Postoperatively, one patient experienced respiratory insufficiency, and two patients required revision of rotational or free myocutaneous flaps. All patients who presented with spine-based pain experienced a reduction in pain, as measured by a visual analog scale for pain. All patients who were neurologically intact preoperatively remained so; seven of seven patients with neurological impairment improved; and six of seven patients improved one Frankel grade. There were no occurrences of instrumentation failure or hardware-related complications. In one patient a revision of the instrumentation was required 13.5 months following the initial surgery for progression of malignant fibrous histiosarcoma.

Conclusions. In selected patients, OCT fixation is an effective means of attaining stabilization that can provide pain relief and neurological preservation or improvement.

KEY WORDS • occiputocervical fixation device • spine • tumor • spinal fusion • spinal stabilization

OCCIPITOCERVICOTHORACIC (OCT) fixation may be indicated for cases in which severe instability in the cervical spine region is present. The results of a literature search revealed three reports of OCT fixation and one case in which OCT fusion was performed without fixation. In 1986, Zigler, et al.,[12] reported a case of traumatic occipitocervical dislocation treated with OCT fusion in which internal fixation was not used. Stabilization was provided by a halo vest, which the patient wore for 4 months until solid fusion occurred. In a series of 13 patients whose rheumatoid disease was treated by occipitocervical fixation and fusion, a single occipital (Oc)–T1 fixation and fusion procedure was performed, after which the patients wore a halo vest orthosis.[6] In a series of 16 patients reported by Fehlings, et al.,[4] in whom occipitocervical fixation and fusion was performed, one patient with neurofibromas underwent Oc–T3 fixation. Another successful OCT fixation and fusion procedure was reported by Seki, et al.,[10] in a patient who had developed kyphosis after laminectomy for resection of a meningioma located in the foramen magnum; a halo vest was also used in this patient. In our literature review, we found few reports of OCT fixation and fusion performed by various methods for instability of diverse causes. No report contained more than one patient who underwent OCT fixation.

We report our experience in a series of 12 consecutive patients whose spinal neoplastic processes were treated by OCT fixation. Special emphasis is placed on technique, pain relief, neurological status, and complications. With this technique, the immediate spinal stability achieved allows early mobilization of the patient without need for a cumbersome external orthosis.

Clinical Material and Methods

Patient Population

Over the past 4 years, 722 spinal operations in 552 patients have been performed by the neurosurgery service at The University of Texas M. D. Anderson Cancer Center. A majority of these procedures were performed to treat spinal neoplasms. In 12 patients who harbored neoplastic lesions of the spine, OCT fixation for spinal instability was required. Indications for surgery included symptomatic spinal

TABLE 1

*Indications for surgery in patients with neoplastic processes involving the occipitocervicothoracic spine**

Case No.	Diagnosis	Indications for Surgery
1	multiple myeloma	C3–5 subluxation, pain, myelop from myelomatous replacement of C3–7, loss of ant column
2	malignant fibrous histiosarcoma	angulation, pain, myelop from ant & pos destructive tumor at C2–5 extending into paraspinal musculature
3	malignant spindle-cell sarcoma	pain, myelop from recurrent tumor at C5–T2, previous C3–7 lam w/ failed fusion at C3–T1
4	metastatic breast cancer	angulation, pain, radiculopathy, cord compression from fractures at C7–T1 w/ metastases at C5–T6
5	lung cancer–chest wall, thoracic spine	angulation, pain from failed C3–T6 fixation after prior T1–2 vertebrectomy, C-7,T-3 lam, Pancoast tumor, ribs 1–4, chest wall resection w/ 360˚ fixation
6	neurofibromatosis	angulation, pain from prior schwannoma resections & multiple fixation/fusion attempts
7	lung cancer–chest wall, thoracic spine	angulation, pain from failed C3–T8 fixation after prior T-2 vertebrectomy, T1–3 lam, Pancoast tumor, & chest wall resection w/ 360˚ fixation
8	neurofibromatosis	angulation, myelop from failed C1–7 lam
9	metastatic breast cancer	angulation, pain, myelop from failed C2–7 strut graft & pos instrumentation of C2–7
10	desmoid sarcoma	tumor at C3–6 laminae, facets, & paraspinal musculature C1–T4
11	lung cancer–chest wall, thoracic spine	angulation, pain from failed C3–T6 fixation after T-1 vertebrectomy, T1–2 lam, resection of Pancoast tumor, ribs 1–3, clavicle, & chest wall w/ 360˚ fixation/fusion
12	synovial sarcoma	occipitocervical instability, pain, myelop from recurrent sarcoma extending from paraspinal musculature occiput–C3–intrascapular, previous resection, & lam procedures

* ant = anterior; lam = laminectomy; myelop = myelopathy; pos = posterior.

TABLE 2

Demographic and clinical data obtained in patients undergoing OCT

no. of patients	12
age (yrs)	
range	23–57
mean	47
sex distribution	7 M, 5 F
diagnosis (no. of patients)	sarcoma (4)
	lung cancer (3)
	breast cancer (2)
	neurofibromatosis (2)
	multiple myeloma (1)
presenting symptoms (no. of patients)	severe axial pain (10)
	neurological compromise (7)
previous treatment (no. of patients)	radiotherapy (7)
	chemotherapy (6)
	spinal surgery (9)
follow up (mos)	
range	1–45
mean	14

cord compression and/or intractable axial spinal pain secondary to instability of the cervical, occipitocervical, and/or cervicothoracic spine. The indications for surgery are listed for each patient in Table 1. Instability was demonstrated on anteroposterior and lateral radiographs of the spine, flexion–extension films when indicated, and/or by axial spinal pain. Axial spinal pain, which is a mechanical pain exacerbated by movement and relieved by recumbency, is associated with a structural abnormality in the spinal column. In all patients estimated life expectancy exceeded 3 months.

The patients' records were retrospectively reviewed, and data were collected on age, gender, and presence of primary and metastatic disease. Medical treatment (chemotherapy, radiotherapy, or both), and previous surgical procedures involving the spine were reviewed (Table 2). Preoperative evaluation included neurological examination, pain assessment, radiography, magnetic resonance imaging, and computerized tomography scanning in selected cases. Neurological function was assessed, and each patient's neurological status was scored using the method of Frankel, et al.[5] Patients rated their pain by using a visual analog scale (VAS).[9] The type and quantity of pain medication consumption were recorded for all patients. Recorded operative data included: procedure, number of internally fixated levels, length of surgery, estimated blood loss, number of transfusions, and type of closure performed. The postoperative length of hospital stay (LOS), number of days until ambulation, and complications were reviewed for each patient. Serial postoperative neurological evaluation, VAS scores, and pain medication consumption were recorded. The mean follow-up period was 14 months (range 1–45 months). Telephone interviews were conducted with patients to obtain additional information.

Operative Technique

Preoperative cervical traction was applied in one patient in whom instability and significant subluxation were present. Selected patients in whom spinal cord compression or preoperative instability was demonstrated underwent fiberoptic intubation and positioning while awake. Patients were placed prone on gel bolsters and cranial pin fixation was used. Optimum positioning and alignment were confirmed using intraoperative radiography. Somatosensory-evoked potential monitoring was performed intraoperatively to assess the physiological integrity of the spinal cord in selected cases.

The suboccipital region, posterior cervical spine, and thoracic spine were exposed in a subperiosteal fashion via a midline incision. Tumor resection and spinal cord decompression were performed prior to the instrumentation and fusion procedure. In situations in which the tumor was too solid to suction and too soft for the high-speed drill, we used an ultrasonic aspirator (Cavitron Ultrasonic Aspirator; ValleyLab, Inc., Boulder, CO). Following tumor resection and complete decompression of the spinal cord and corresponding roots, attention was turned to OCT segmental fixation. In patients with instability caused by failure of previously placed hardware, old spinal hardware was removed in its entirety prior to OCT fixation.

By using an aluminum template rod, a template was fashioned of the intended shape of the titanium rod to be placed from the occiput to thoracic spine. Two 6-mm-diameter titanium rods (Universal Spinal System; Synthes Spine, Paoli,

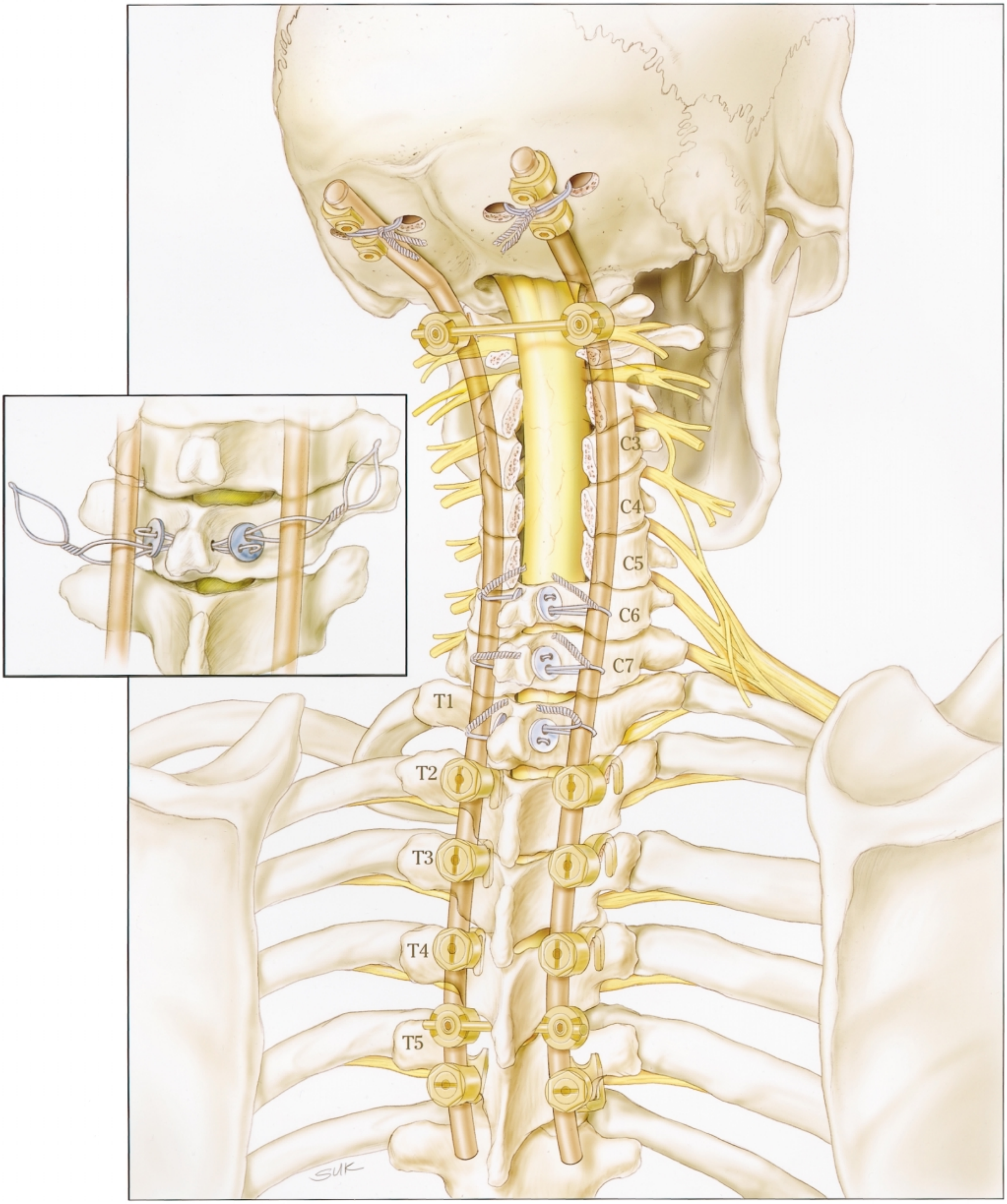

FIG. 1. Artist's rendering of occipitocervicothoracic fixation. *Inset:* Closer view depicting Wisconsin interspinous process wiring technique.

PA) were then bent to fit the curvature from the occiput to the cervical and thoracic spine. Two burr holes (1-cm diameter and more than 1 cm apart) were placed on each side of the midline, approximately 2.5 cm rostral to the foramen magnum. After dissecting the dura mater from the inner table of the skull, two Luque wires were passed from burr

TABLE 3

*Results of OCT fixation**

Case No.	Diagnosis	Age (yrs)	Procedure	Wound Closure	Frankel Grade Pre-op	Frankel Grade Post-op	Pain Reduction	Days Until Walking	LOS (days)	Follow Up in Mos (status)	Complications 0–30 days
1	multiple myeloma	49	reduction of cervical subluxation; Oc–T4 fix	simple	D	E	yes	5	6	45	postop supraventricular tachycardia for 12 hrs, asymptomatic
2	malignant fibrous histiosarcoma	58	resection of tumor C2–5, Oc–T7 fix, 2nd-stage ant resection & fibula strut C2–5	simple	D	E	yes	3	8	22 (died)	nasal trauma caused by nasal gastric tube
3	malignant spindle-cell sarcoma	46	resection of tumor C5–T2; Oc–T7 fix	simple	C	D	yes	8	27†	4 (died)	UTI
4	metastatic breast cancer	52	resection of tumor C7–T1; Oc–T6 fix	simple	D (improved)	D	yes	2	8	1 (died)	readmission 21 days postop for altered mental status caused by hypercalcemia
5	lung cancer–chest wall, thoracic spine	35	removal C3–T6 instru; Oc–T6 fix	simple	E	E	yes	1	2	5 (died)	none
6	neurofibromatosis	54	removal C2-T4 instru; Oc–T6 fix	bilat trapezius, rt latissimus dorsi	E	E	yes	7	10	26 (employed)	congested flap requiring leeches; respiratory insufficiency
7	lung cancer–chest wall, thoracic spine	54	removal instru C3–T8; Oc–T8 fix	bilat trapezius	E	E	yes	4	6	28 (employed)	separation of trapezius flap closure requiring advancement
8	neurofibromatosis	50	resection tumor; Oc–T6 fix	simple	C	D	yes	30	14†	17	UTI while in rehabilitation
9	metastatic breast cancer	55	removal of ant C2–7 strut & post instru; Oc–T5 fixation	simple	D	E	yes	5	15†	6 (died)	none
10	desmoid sarcoma C1–T4	23	resection of sarcoma C1–T4, Oc–T8 fix	bilat trapezius	E	E	no	2	9	11	flap seroma, no treatment
11	lung cancer–chest wall, thoracic spine	57	removal C3–T6 instru; Oc–T6 fix	simple	E	E	yes	3	6	3	none
12	synovial sarcoma	30	resection occipitoscapular sarcoma; Oc–T5 fix	rectus free flap	D	E	yes	12	20†	3 (died)	free rectus flap failure requiring revision

* fix = fixation; instru = instrumentation; UTI = urinary tract infection.

† LOS includes days in inpatient rehabilitation.

hole to burr hole on each side. Segmental fixation to the cervical spine was achieved using Wisconsin interspinous process wires[3] and in certain cases by using sublaminar wiring at C-1. A combination of titanium alloy transverse process hooks and pedicle hooks (Universal Spinal System) were used in the thoracic spine to achieve a hook-and-claw configuration. The contoured and cut 6-mm-diameter titanium rods were then attached to the wires and cables in the occiput and cervical spine and to the hooks in the thoracic spine. Crosslinks were subsequently placed to provide increased torsional stability (Fig. 1). The wound and instrumentation were copiously irrigated with a diluted antibiotic solution. Selective decortication of the occiput, lateral masses, transverse processes, and laminae was performed using a high-speed drill and followed by placement and packing of cadaveric bone chips that were mixed with demineralized bone matrix. Closed suction drainage catheters were placed as needed. Four patients required rotational or free myocutaneous flap closure because of the presence of large soft-tissue defects caused by tumor resection.

Postoperatively, no patient was placed in a cervical collar or halo vest. One patient required a halo vest 17.5 months after surgery due to special circumstances (see *Complications*).

Results

Operative and Perioperative Data

Twelve patients with spinal neoplastic disease underwent OCT fixation and fusion (Table 2). In all 12 patients spinal instability was secondary to direct tumor invasion and/or iatrogenic instability that followed tumor resection. In three patients OCT fixation was performed as a primary procedure following reduction of subluxation (Case 1) or following tumor resection (Cases 4 and 10). The remaining nine patients had undergone one to four previous spinal operations in the region of interest. These nine patients required OCT fixation for instability caused by recurrent tumor (Cases 2, 3, and 12), from failure of the fixation procedure performed at the time of previous tumor resection (Cases 5–7, 9, and 11), or from iatrogenic instability caused by previous tumor resection in which fixation was not performed (Case 8). The patient in Case 2 underwent OCT fixation and tumor resection prior to a planned second-stage anterior approach to tumor resection in which C2–5 fibula strut grafting was used.

The median operative time was 8.3 hours (range 5.5–13.75 hours). Increased operative time was associated with extensive tumor resection (five of 12 patients) and rotation-

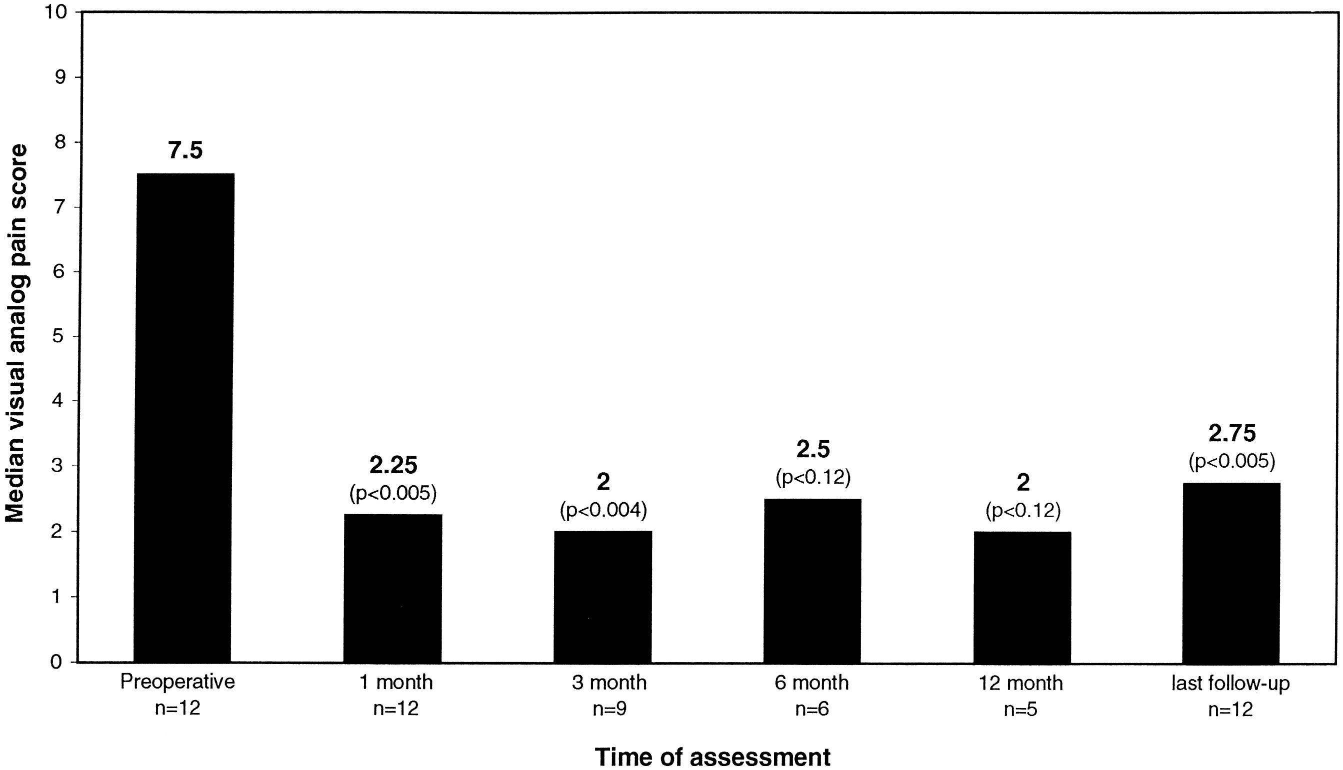

FIG. 2. Bar graph showing the median VAS pain scores preoperatively and at subsequent postoperative assessments following OCT fixation. A VAS pain score of 10 indicates severe pain and a score of 0 indicates no pain. n = the number of patients examined at follow-up interval.

al or free myocutaneous flap closure (four of 12 patients). Estimated intraoperative blood loss (median estimated blood loss 1350 ml; range 300–3700 ml) was expectedly higher in cases of tumor resection and myocutaneous flap closure. Halo vests or cervical collars were not used postoperatively on a routine basis (see *Complications*).

Patients were mobilized as soon as possible. By a median of 4.5 days postoperatively (range 1–30 days), patients were ambulatory with or without use of assistive devices. All patients were observed in the surgical intensive care unit for at least 1 night (median 1 day; range 1–13 days). The median LOS including the time spent in the intensive care unit, acute care, and in certain cases, inpatient rehabilitation was 8.5 days (range 2–27 days).

The clinical details and results for the 12 patients with spinal neoplasms who underwent OCT fixation and fusion are summarized in Table 3. The first and last cases are presented in further detail.

Neurological Outcome

Preoperatively, seven patients experienced neurological compromise secondary to direct spinal cord compression. All patients who were neurologically intact preoperatively remained so, and all seven patients with neurological impairment improved when compared with their preoperative states. Six of these patients improved by one Frankel grade. There was no case of a neurological decline secondary to surgery. The neurological outcome of the patients in this series is presented in Table 3.

Pain Status

Preoperatively, 10 of 12 patients presented with severe axial pain secondary to instability. All 10 of these patients experienced decreased pain postoperatively. One patient who presented with a large sarcoma and very minimal preoperative pain complained of significantly increased and persistent pain and stiffness postoperatively (Case 10). The preoperative median VAS score was 7.5. This median VAS score decreased to 2.25 at 1 month, 2 at 3 months, 2.5 at 6 months, 2 at 1 year, and 2.75 at last follow-up examination (Fig. 2). The reduction of pain status at the time of discharge, 1 month, 3 months, and at last follow up was found to be statistically significant when analyzed using the exact Wilcoxon signed-rank test. Quality and quantity of total pain medication consumption decreased in eight of 12 patients postoperatively when compared with preoperative consumption. Pain relief was found to be immediate and long lasting.

Major and Minor Complications

All adverse events that occurred within 30 days of surgery were considered complications. Complications that required additional surgery, caused an increased LOS, or those that were potentially life threatening were considered major complications. Complications that did not significantly change the overall course of events and that did not increase LOS were considered to be minor. All complications are listed in Table 3.

There were five major complications in four patients.

The patient in Case 4 developed hypercalcemia and altered mental status secondary to malignancy 13 days after discharge from the hospital (21 days postoperatively) and required readmission. These complications were corrected; however, 1.3 months postoperatively this patient died secondary to metastatic breast cancer. The patient in Case 6 developed respiratory insufficiency that was thought to be caused by a large intraoperative fluid load, which required 4 days of mechanical ventilation. This patient also experienced venous congestion of her myocutaneous flap, which required medical leech treatment. She was discharged home without sequelae on postoperative Day 10 and is currently employed as an elementary school teacher. The patients in Cases 7 and 12 required revision of their myocutaneous flap closures. There were no cases of neurological complication or instrumentation-related failure. Most major complications were associated with free or rotational myocutaneous flap closures.

Five minor complications in five patients included asymptomatic postoperative supraventricular tachycardia for 12 hours, nasal trauma secondary to nasal gastric tube placement, urinary tract infection in two patients, and one case in which the myocutaneous flap seroma did not require treatment.

Symptomatic local recurrences occurred in two patients (Cases 2 and 12). The patient in Case 2 developed recurrent malignant fibrous histiosarcoma at 13.5 months postoperatively; treatment required repeated resection and revision of the OCT instrumentation. Four months later this patient was required to wear a halo vest for instability caused by recurrent destructive spine and skull base tumor. He died 4 months later. Two months postoperatively, the patient in Case 12 developed an intracerebral hemorrhage caused by recurrent tumor involving the sigmoid and transverse sinus and was subsequently referred for hospice care. She died 3 months postoperatively.

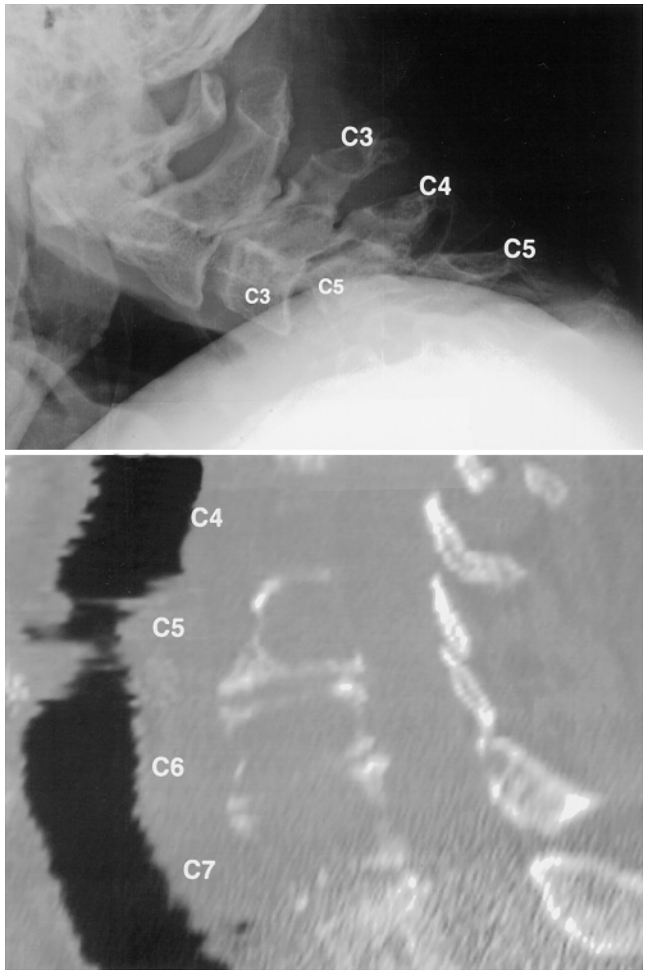

FIG. 3. Case 1. *Upper:* Preoperative lateral cervical spine radiograph revealing subluxation at C3–5. *Lower:* Sagittal computerized tomography reconstruction of the cervical spine after reduction procedure, demonstrating myelomatous replacement of vertebral bodies.

Illustrative Cases

Case 1: Multiple Myeloma with C3–5 Subluxation and Cord Compression

The first patient in this series was a 49-year-old man with advanced multiple myeloma affecting the skull, humerus, ilium, ischium, scapula, and ribs, as well as the cervical, thoracic, and lumbar spine who developed a C3–5 subluxation myelomatous replacement of the C3–7 vertebral bodies, as well as renal failure due to hypercalcemia (Fig. 3). Preoperatively he underwent radiotherapy and chemotherapy. He suffered from severe axial spinal pain that he rated as 9 of 10 on the VAS, which required patient-controlled intravenous narcotic analgesia. The subluxation and myeloma were rated Frankel Grade D, high–cervical spinal cord impairment. This patient had complete anterior column failure, destruction of the C-4 body, and myelomatous replacement of C3–7, as well severe osteopenia. An anterior multilevel corpectomy and reductive procedure, followed by strut graft and anteroposterior instrument placement, was a potential treatment option in this patient. However, considering the poor quality of his bone and the need to perform a four- to five-level anterior corpectomy, we elected a posterior approach to perform the reduction and fixation procedures.

We performed a closed reduction procedure while the patient was awake in which in-line cervical traction was used and followed by an Oc–T4 segmental fixation (Fig. 4). The fixation segment was extended from the occiput to the thoracic spine because failure would likely occur one or two levels above and below the area of injury if we used a shorter fixation segment into osteopenic bone without anterior column support. Because the condition of this patient was presumed near-terminal, a fusion procedure was not performed. This patient experienced immediate postoperative pain relief and improvement in neurological function. By postoperative Month 6 this patient was neurologically intact, with Frankel Grade E function. This patient experienced minimal pain and was neurologically intact 45 months post-OCT fixation, and there was no evidence of instability or instrumentation failure. His multiple myeloma has been in remission. All patients treated subsequent to this case have undergone a fusion procedure performed following OCT fixation regardless of their presumed life expectancy.

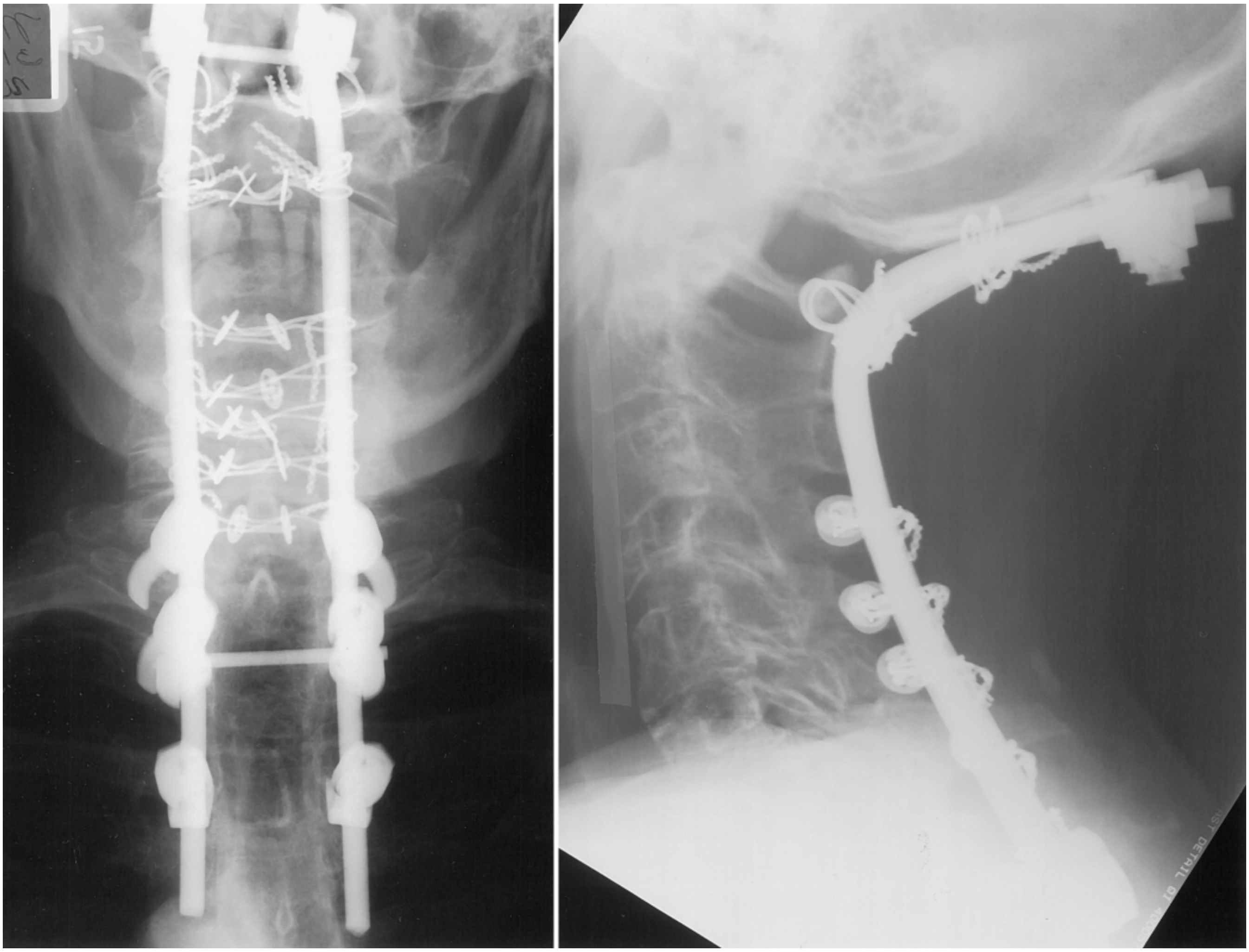

FIG. 4. Case 1. Postoperative radiographs obtained 40 months after surgery demonstrating anteroposterior *(left)* and lateral *(right)* views of OCT fixation.

Case 12: Recurrent Synovial Sarcoma With Spinal Cord Compression

The last patient in this series was a 30-year-old woman in whom a diagnosis of synovial sarcoma involving C3–T1 had been made. She underwent preoperative chemotherapy, wide local excision with C3–4 laminectomy, and myocutaneous flap closure. She underwent conventional external radiotherapy. One and a half years later, repeated resection and brachytherapy were performed. This patient did well for an additional 7 months until she returned with severe cervical pain and myelopathy (Frankel Grade D). Magnetic resonance imaging revealed extensive tumor recurrence (Fig. 5) extending from the occiput through C1–2 into the spinal canal. The paraspinal musculature from the occiput to the scapula was infiltrated with sarcoma. A C1–2 laminectomy was performed to remove extradural tumor from the region of the upper cervical spine. Additional extraspinal tumor was resected from the occiput to the scapula. An Oc–T5 fixation and fusion procedure was performed to provide stabilization (Fig. 6). In this patient instability was thought to be secondary to the C1–4 laminectomy combined with complete resection of the bilateral paraspinal musculature from Oc–C7. Closure was achieved with a free myocutaneous flap. Postoperatively, she experienced significant relief of pain (preoperative VAS score of 7; postoperative VAS score of 2), as well as resolution of her myelopathy. Her postoperative course was complicated by a vascular failure of the free myocutaneous flap necessitating a revision. She was discharged home in good condition only, unfortunately, to return 2 months later with an intracerebral hemorrhage secondary to skull base tumor invasion and sinus thrombosis. She died 3 months after undergoing tumor resection and OCT fixation.

Discussion

In this report we describe a safe and effective technique of using rigid internal fixation to provide stability to the occipitocervicothoracic region in patients with instability caused by neoplastic processes or the treatment of such processes. The method of fixation is a modification of the occipitocervical fixation technique described so well by

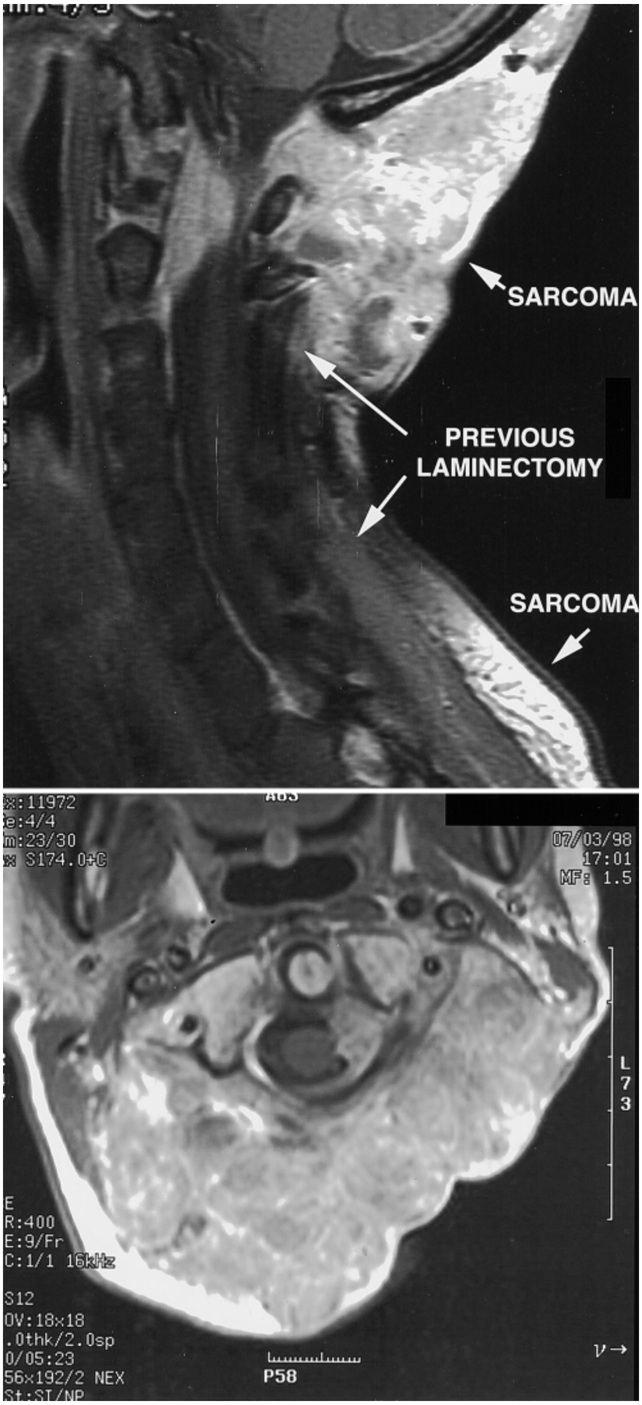

FIG. 5. Case 12. Preoperative contrast-enhanced sagittal *(upper)* and axial *(lower)* MR images demonstrating recurrent posterior occipitocervical sarcoma.

Fehlings, et al.,[4] which, in turn, is an adaptation of occipitocervical fixation techniques described by others.[6–8,11] Because of the length of fixation (average 14 motion segments), we have used two 6-mm titanium rods that are intraoperatively contoured and crosslinked, instead of a single U-shaped rod. In the aforementioned few reports, OCT fixation has been performed using spinous or sublaminar wires in the thoracic spine, and external orthosis (halo vest and cervical collar) for additional support. In the thoracic spine, we have used transverse process and pedicle hooks for segmental fixation. Immediate and durable rigid fixation is achieved, thereby eliminating the need for postoperative external orthosis.

No patient in our series developed solid bridging bone over the entire length of the fixation. Despite the time-honored dictum that all instrumentation will eventually fail unless spinal fusion occurs, in this series there were no cases of instrument failure, and only one patient eventually required placement of an external halo orthosis (at 17.5 months postoperatively) due to extensive recurrent destructive spinal and skull base tumor. In the patient in Case 1 there is no evidence of instability or instrument failure 45 months after OCT fixation. The reason for absence of radiographically demonstrated bone fusion may be a result of the neoplastic disease process and its associated catabolism. In addition, most of these 12 patients underwent radiotherapy (10 patients) and/or chemotherapy (eight patients) and had a long length of fixation (average of 14 motion segments). All of these factors would probably decrease the fusion rate. The follow-up period and expected survival time are also relatively short when compared with series in which fusion outcome is assessed in patients without neoplastic diseases. The rate of solid spinal fusion could probably be improved with the use of autograft bone;[1,2] however, in this patient population with relatively short expected survival times we elected to use cadaveric bone chips (which are now supplemented with demineralized bone matrix) to minimize operative pain and morbidity related to bone graft harvesting.

By design, OCT fixation greatly reduces spinal mobility. Therefore, this procedure was only performed in carefully selected patients with severe impairment secondary to pain or neurological compromise from neoplastic disease, and/or in those with iatrogenic spinal instability resulting from tumor resection. As a result of pain, instability, or neurological compromise, preoperative ambulation and mobility were severely limited in a majority of these patients. In these patients OCT fixation provided immediate spinal stability, which significantly reduced or eliminated their axial spinal pain. In addition, all patients who sustained preoperative neurological deficits experienced improved neurological function postoperatively. Despite a significantly limited range of spinal motion postoperatively, almost all patients were more comfortable and more ambulatory after OCT fixation. Two of three patients who were employed preoperatively returned to work and were employed at last follow-up visit. Overall patient functional status was improved postoperatively due to reduced pain and reduced neurological impairment.

Conclusions

Occipitocervicothoracic fixation and fusion is an infrequently performed procedure for the treatment of severe spinal instability; there are only a few previously reported cases. Occipitocervicothoracic fixation can be achieved by attaching two intraoperatively contoured and subsequently crosslinked titanium rods to the occiput by using burr holes and Luque wires/cables, to the cervical spine by using Wisconsin wires, and to the thoracic spine by using

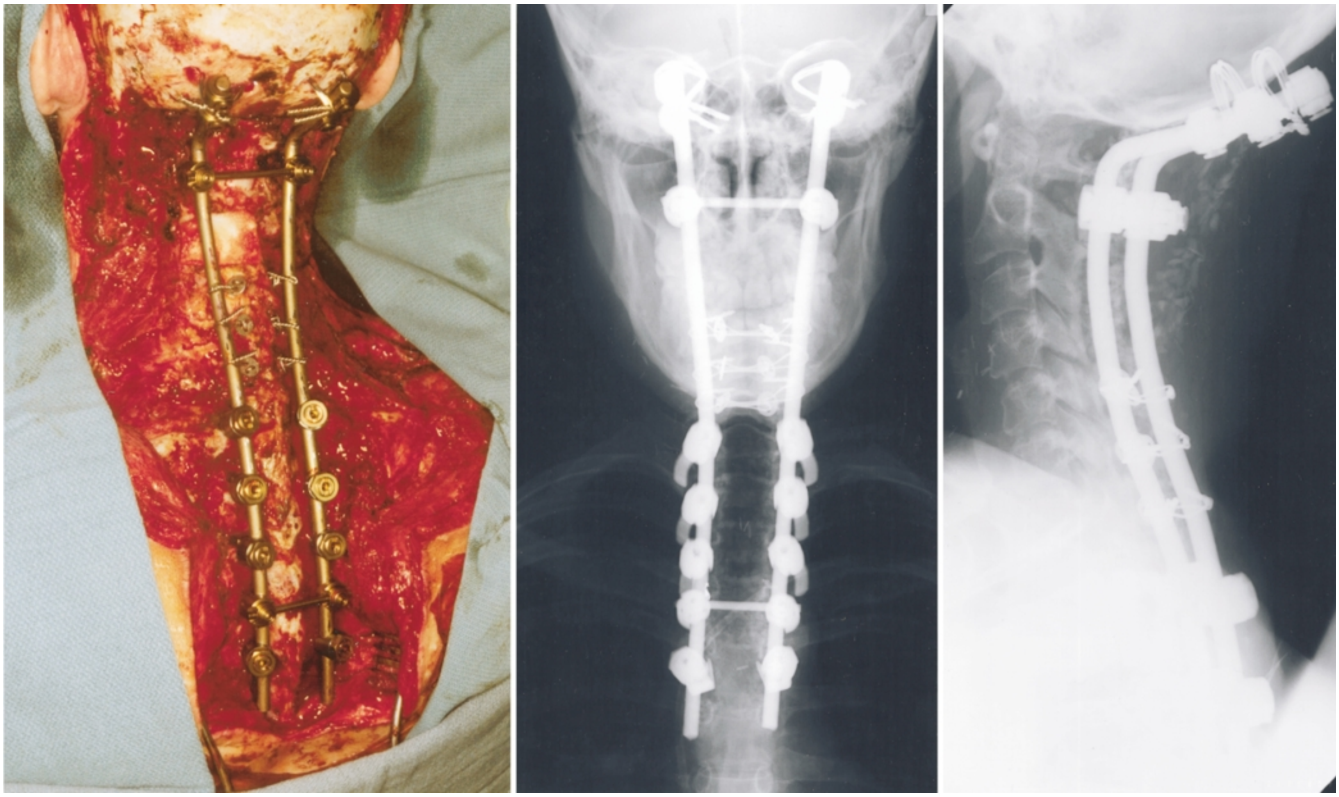

FIG. 6. Case 12. *Left:* Intraoperative photograph demonstrating resection of sarcoma and OCT fixation. *Center* and *Right*: Anteroposterior and lateral radiographs obtained postoperatively.

a combination of transverse process and pedicle hooks. This procedure can be performed safely with minimal complications, especially if simple, primary closure is achieved. In patients with neoplastic processes affecting the occipital, cervical and upper thoracic spine regions, this is an effective and durable method to obtain immediate stabilization that can provide significant pain relief and neurological preservation or improvement.

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