Highlighting Laboratory Research and Clinical Advances in Spine Health

A Message from Gordon R. Bell, MD
Director, Center for Spine Health

The 2011 issue of Spinal Column heralds a new format for this publication of the Center for Spine Health (CSH). Previous issues were biannual and generally theme-oriented. Commencing with this edition, Spinal Column will be a once-yearly publication and will be more general in scope, encompassing a larger number and wider array of interesting and timely articles.

This issue of Spinal Column features eight articles encompassing clinical topics, as well as ongoing laboratory and clinical research efforts in the Center for Spine Health.

An article by Dan Mazanec, MD, provides a concise history and overview of the workers’ compensation system. This article provides valuable insights for those physicians treating patients with workers’ compensation claims. In a similar vein, Tagreed Khalaf, MD, presents a summary of the functional capacity evaluation (FCE), an objective measure of workers’ capability to perform work tasks. Dr. Khalaf describes the components, limitations and reliability of the FCE.

Toomas Anton, MD, provides a brief, well-balanced summary of the current role of minimally invasive surgery (MIS) for spinal disorders. The benefits and potential drawbacks of MIS are described, and its role as an alternative to conventional surgery is discussed.

Ajit Krishnaney, MD, and Edward Benzel, MD, describe the intricacies of surgery at the craniocervical junction. Surgery at the uppermost portion of the spine is particularly delicate and challenging because of the unique anatomy involved. This makes both the exposure and fixation of this part of the spine potentially difficult.

Edward Covington, MD, provides a thought-provoking perspective on the role of opioid therapy for chronic spine pain. This topic has attained a level of national notoriety because of the explosive use of powerful and addictive narcotic medication for what is essentially a benign condition. Dr. Covington concludes with some well-thought-out recommendations for opioid use in patients with chronic pain.

Head injury in sports, particularly in football, is a very topical and emotionally charged issue that has generated significant clinical and research activity. Major efforts are under way to identify those players at risk for head injury, to develop and implement screening tools that provide baseline values for use in determining return-to-play following head injury, and to improve the safety of sports equipment. The article by Edward Benzel, MD, and Adam Bartsch, PhD, from the Spine Research Laboratory (SRL) describes the multidisciplinary Cleveland Clinic efforts in studying the neuromechanics of concussion and subconcussive injury, in developing technologies to evaluate it and in educating the public about this potentially devastating condition.

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Research Efforts at Epicenter of Concussion Crisis

By Edward Benzel, MD, and Adam Bartsch, PhD

An increasingly intense governmental and media focus on the brain health implications of concussion in youth, collegiate and professional athletes is evident. Recently, as a possible sequela of the cumulative effect of clinically symptomatic concussive and clinically silent subconcussive impacts, the careers (and in some cases, the lives) of a number of high-profile football players have ended prematurely.

Concerns regarding the immediate and long-term effects of multiple concussive and subconcussive impacts on the brain health of football players have led to escalating demand for improvements in helmet design and testing standards as well as for a re-evaluation of athlete training regimens and on-field safety-related rules and regulations. In spite of the heightened awareness surrounding concussion, much still remains unknown about risks of football-related head impact dosage. Most important, in 2011 the state of Ohio and the U.S. Congress recognized the urgent need to help protect millions of children playing tackle football from concussion by introducing legislation to mandate standard means by which to evaluate the protection provided by youth football helmets.

Cleveland Clinic’s Center for Spine Health, Department of Neurosurgery and Spine Research Laboratory (SRL) are aggressively studying the traumatic neuromechanics of concussion and subconcussive injury. The testing of protection by football helmets showed that in certain instances pre-World War II-era leather helmets performed on par or better than some helmets currently used in high school, college and professional football (Figure 1). Similar SRL studies on boxing and mixed martial arts protective padding demonstrated that padding the head and hand did not always appreciably reduce risk of head and neck trauma (Figure 2). A 2011 NFL Charities grant to Cleveland Clinic will allow researchers to study the effects of cervical spine protection on concussion risk in youth sports. This work...
is desperately needed, because current youth helmets are essentially scaled-down “little adult” versions of adult helmets.

Efforts toward developing the first impact dosimeter, also known as the “Intelligent Mouthguard,” are moving forward at full speed (Figure 3). Aided by Cleveland Clinic Product Development Funds and the NFL Charities grant, it is anticipated that the first in vivo Intelligent Mouthguard impact dosage data will be collected before the end of 2011. All these efforts are aided by recent innovations in finite element analysis and the ability to pinpoint “hotspots” within the brain for further clinical injury analysis (Figure 4).

Just Part of a Larger Concussion Research Effort

These initiatives within Center for Spine Health’s Department of Neurosurgery and Spine Research Laboratory are part of a larger movement within Cleveland Clinic. Each project is integrated with Cleveland Clinic-wide concussion initiatives. These include partnering with Sports Health clinicians Rick Figler, MD, and Bob Gray, ATC, to appear at regional coaches’ clinics and on local radio to discuss the concussion risks and best practices. They will partner with Jay Alberts, PhD, Associate Staff in the Department of Biomedical Engineering in Cleveland Clinic’s Lerner Research Institute, and his internet cognitive motor evaluation and testing system (I-COMET) for sideline return-to-play decision
making. Michael Phillips, MD, Vice Chair of Research and Academics in the Department of Diagnostic Radiology, is investigating advanced brain injury neuroimaging. Damir Janigro, PhD, Staff in both the Cerebrovascular Center and Lerner Research Institute’s Department of Cell Biology, and Nicola Marchi, PhD, Project Staff in Cell Biology, are exploring brain-injury blood biomarkers. The projects hold high promise to be paired soon with our traumatic neuromechanics work.

Cleveland Clinic is uniquely poised to help resolve the concussion crisis. There are few places on Earth where such a unique and talented selection of clinical and basic science researchers can rub elbows on a daily basis. With the continued cross-pollination of Center for Spine Health’s Department of Neurosurgery and Spine Research Laboratory research efforts with other concussion domains within Cleveland Clinic, much will be done to ensure athletic competition is as safe as possible and long-term brain health is preserved in all who participate in contact sports.

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REFERENCES

Figure 4. Finite element analysis allows for theoretical injury ‘hotspot’ identification from actual on-field or laboratory impact dosage data.
Kinematic Analysis of a Golf Swing in Lumbar Degenerative Disease

By Edwin Capulong, MD

There are roughly 50 million golfers worldwide, including more than 26 million in the U.S., according to the National Golf Foundation. Approximately 50 percent are older than 40, a time when lumbar degenerative disorder (LDD) becomes symptomatic.

Cleveland Clinic researchers conducted a pilot study to compare the golf swings of subjects who had LDD and back pain with those of subjects who had no LDD (controls). Because of the inherent asymmetric pattern of “torque and stress” during the golf swing, it is hypothesized that kinematic adaptations are needed to prevent back injury in subjects with LDD.

Back Injury in Golf

Potential causes of low back pain secondary to golf include asymmetrical swing pattern, overuse, improper technique, swing changes and poor conditioning.

Most golf injuries occur from the top of the backswing to ball impact, brought about by increases in velocity and magnitude of muscular activity to maximize shoulder/pelvic separation and increase ball distance. However, this torsion and muscle contraction increase axial and facet loading, which can result in back injury. This “spinal stress” can be detrimental in the presence of lumbar disc degeneration.

We reviewed several published reports regarding low back pain and golf swing, but no study currently associates radiographic evidence of L4 or L5 lumbar degenerative disorder with kinematic changes of the golf swing and pain behavior.

Golf Swing Kinematics

The golf swing is a complex movement that requires a sequence of muscle activity, multiple joint movement, ground reaction forces and spinal loading. There are three phases:

- Swing phase — ball address to ball impact
  - Setup, establishing the grip and positioning the body with respect to the ball
  - Backswing, aka takeaway phase; ball address to top of the backswing, resulting in rotation of club head away from the ball

- Forward swing, top of the backswing to club in a horizontal position; early part of downswing

- Acceleration, horizontal club position to ball impact; later part of downswing

- Early follow-through impact to horizontal club position on the opposite swing

- Late follow-through horizontal club position to completion of swing

At ball address, the primary spinal angle (trunk flexion relative to hip) is approximately 45 degrees, while the secondary spinal angle (right lateral bending of the spine, with slight depression and downward rotation of the arm and scapula) is approximately 16 degrees. Knees are flexed at 20 to 25 degrees and weight distribution is 50 to 60 percent toward the right foot for a right-handed golfer.

During backswing, the arms and chest form a triangle throughout the swing plane. At the top of the backswing, the right arm is abducted and externally rotated, while the right elbow is in flexion. The left arm is adducted and internally rotated. The left leg of the right-handed golfer will bear approximately 40 percent of body weight.

As the golfer rotates during the acceleration phase, the right erector spinae and abdominal muscles contract along the swing plane. Deceleration is achieved during follow-through using eccentric contractions. The left shoulder is abducted and externally rotated, and the right shoulder is adducted and internally rotated. Spine and hips are rotated to the left, with the left knee absorbing more than 50 percent of the weight.

The muscles relevant to lumbar stabilization are the trunk extensors and abdominal muscles. Further stability is achieved by increasing trunk muscle coactivation (external oblique, internal oblique and transversus abdominis muscles), thereby increasing trunk stiffness in preparation for a sudden loading.
The erector spinae, quadratus lumborum and rectus abdominis muscles also provide trunk stability. Surface EMG studies showed that myoelectric activity is highest during the acceleration phase and lowest during the backswing, or takeaway.

**The X Factor and X Factor Stretch**

In 2002, McLean described the concept of the X factor, in which he proposed that shoulder/pelvic separation during the backswing will improve ball distance. Later, McLean and Cheetham extended this concept, proposing that the “X factor stretch” be at the beginning of the downswing rather than the backswing. The X factor stretch became part of golf instruction and has been researched by Myers et al., who have correlated it with ball distance. How much of this stress loading affects the spine in the presence of radiographic LDD is not known.

**Methodology**

All subjects were right-handed males comparable in age, weight, height and golf handicap. Mean was calculated between groups (LDD vs. control), looking at golf swing kinematics and pain behavior measurements taken pre- and post-golf swing. The relationships between club head speed and the X factor and X factor stretch were examined using a 240-frame-per-second optical system in the Biomechanics Laboratory at Cleveland Clinic Lerner Research Institute. Pain behavior measurements were documented using functional outcome/pain behavior.

**Results**

Researchers completed a pilot investigation of 11 subjects (five controls vs. six LDD).

**Table 1: Comparison between groups of pelvic hip separation (measured in degrees) at selected golf swing stages, average linear velocity of the club head speed (measured in meters per second) from backswing to follow-through using a seven-iron.**

<table>
<thead>
<tr>
<th>Address</th>
<th>Top of Backswing</th>
<th>Ball Contact</th>
<th>X Factor Max</th>
<th>X Factor Stretch</th>
<th>Club Downswing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (A)</td>
<td>3.544</td>
<td>27.37453</td>
<td>4.77</td>
<td>28.39752</td>
<td>1.02329713</td>
</tr>
<tr>
<td>LDD (B)</td>
<td>6.068333</td>
<td>22.19517</td>
<td>2.786667</td>
<td>22.57509</td>
<td>0.35171</td>
</tr>
</tbody>
</table>

We found that LDD subjects have lower X factor maximum, or shoulder-hip separation; X factor stretch; and club head velocity (from top of backswing to follow-through).

**Table 2: Comparison between groups of pain behavior and functional outcome.**

<table>
<thead>
<tr>
<th>SF MPQ</th>
<th>PDS</th>
<th>OSW</th>
<th>BDI</th>
<th>Pain Pre-GS</th>
<th>Pain Post-GS</th>
<th>Global Perceived Effect Post-GS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10.4</td>
<td>2</td>
<td>3.2</td>
<td>1.4</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>B</td>
<td>38.9</td>
<td>17.5</td>
<td>22.6</td>
<td>4</td>
<td>2.6</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Pain behavior measurements pre- and post-golf swing were collected. LDD subjects had greater values on the short-form McGill Pain Questionnaire (SF-MPQ), Oswestry Disability Index (OSW), Beck Depression Inventory (BDI), Global Perceived Effect (GPE) and pain discomfort scale from 0 to 10. High SF-MPQ and OSW scores are suggestive of moderate disability among LDD subjects.

Higher pain scores are seen across the golf swing in the LDD group, but the “follow-through” pain is highest compared with other swing stages. This finding differs from prior study results showing increased discomfort at ball impact.

**Discussion**

It appears that LDD subjects’ golf swings are affected by anatomical limitations due to degenerative changes inherent in the aging spine. As the spine and other joints mature, there is less flexibility due to stiffness during the golf swing, which may affect the X factor. Perhaps this, in addition to pain, inhibits the X factor stretch, affecting “efficiency” of the golf swing.

Although our LDD subjects showed moderate degrees of disability, they could perform the golf swing.

For future studies, increasing the power may result in a significant difference between groups regarding the X factor stretch, which could serve as a “kinematic fingerprint” to measure improvements in efficiency and in therapy or its impact in injury prevention.

**Suggested Reading**


Cheetham PJ, Martin PE, Motzam R, St. Laurent BF. The importance of stretching the X-factor in the golf downswing. Communication to the 2000 Pre-Olympic Congress; Sports Medicine and Physical Education International Conference on Sport Science, Brisbane, QLD, Australia.


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*Also contributing to this article: Tammy Owings, PhD; Rhonda Boyko; and Jeff Ciolek, PT.*
Current State of Minimally Invasive Spine Surgery

By Toomas Anton, MD

During the last several decades, there have been significant technological achievements in modern spine surgery. Minimally invasive surgery (MIS), which combines principles of endoscopy and microsurgery, was conceived more than a century ago, and there are reports about the use of endoscopy by Philip Bozzini as early as 1806. Modern MIS arrived in the United States in 1997, when Foley and Smith attached an endoscope to a tubular retractor system.1 Since then, MIS techniques applicable to all areas of the spine have evolved rapidly.

The principle of MIS is to use portals or limited corridors for surgical approaches which decrease surgical tissue trauma. One potential downside of conventional open surgery is the tissue damage that occurs during dissection, retraction and blood vessel cauterization.

The potential benefits of MIS include decreased tissue injury, decreased blood loss, decreased requirements for narcotics, quicker return to work, smaller surgical incisions, less scarring and shorter hospital stays.

Evolving Technology Treats a Wide Range of Conditions

MIS has evolved from simple diskectomy and foraminotomy to complex surgical techniques used to correct or treat deformity, tumors, instability and fractures, and much more. As MIS techniques have developed, so have advancements in retractors, optics and subsets of instruments.

As more surgeons become involved with MIS, it is worth noting that there is a significantly steep learning curve, exposure to radiation and increased surgical time. Not all patients are appropriate for MIS, and as with other open procedures, patients should undergo conservative management, including physical therapy and pain management.

One of the most common spine surgery procedures is decompression for lumbar stenosis. Nearly 38,000 procedures were performed in the U.S. Medicare population in 2007.2 Lumbar stenosis is a major cause of lower back pain, leg pain and disability. Advanced MIS introduced the concept of the unilateral approach for a bilateral decompression. Using that technique, the ipsilateral side is decompressed first, followed by contralateral canal and lateral recess. This approach enables the surgeon to decompress the spinal canal by unilateral approach — preserving spinous processes and decreasing procedural instability. This also helps preserve facet joints and has been effective with neurogenic claudication or radiculopathy. In the face of spondylolisthesis, lateral listhesis and scoliosis, the revision surgery rate is as high as 50 percent and simple decompression is not recommended.
Balancing Caution With Benefits

With all the advancements of MIS, reports recommend exercising caution with the technique. Patient selection and the surgeon's level of experience with the technique seem to be paramount.

There are reports that support less favorable outcomes for leg pain, back pain and perceived recovery after tubular diskectomy in comparison to conventional microdiskectomy. Also, a recent randomized, controlled trial demonstrated no difference in muscle damage between techniques, but patients who underwent tubular diskectomy reported more lower back pain during the first year after surgery.

In summary, MIS is evolving rapidly. It is a safe alternative to conventional surgery. However, this surgical approach should be individualized based on pathology, patient and the surgeon's comfort level with the technique.

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Next-Generation Robotic Testing in the Spine Research Laboratory

By Adam Bartsch, PhD, and Robert McLain, MD

Cutting-edge robotic tests to study spine biomechanics — aka “robo-mechanics” — represent the next frontier in spine research. Cleveland Clinic Spine Research Laboratory (SRL) recently completed its first spine robo-mechanics studies with “Bender,” our in-house spine-testing robot (Figure 1; Kuka Robotics Corp., Augsburg, Germany).

Whereas traditional 20th-century spine research test protocols were limited to use of cables and pulleys to bend the spine (quasi-static test) and simplistic push-pull or twist tests to measure the response of passive spine structures (bones, ligaments, discs) only, Bender allows SRL to conduct state-of-the-science, six-degree-of-freedom, in vitro spine testing in any conceivable orientation, position or load (Figure 2). These tests allow for precise characterization of the intact, injured and stabilized spine while providing groundbreaking insights into the theoretical muscular and neural responses of the in vivo spine.

Spinning at 615 Degrees per Second

Robots like Bender have a long history in industrial settings such as automotive assembly and precision welding and painting, as well as in modern amusement park rides and movies. Robots are still regarded as novelties in medical research.

At the SRL in Cleveland Clinic’s Lutheran Hospital, Bender elevates existing spine research capabilities. The robot allows SRL researchers as well as Center for Spine Health and Department of Neurosurgery staff, fellows and residents to add measurements of active (muscle) and neural (central nervous system) spine responses to the traditionally measured passive spine responses (Figure 3).

To facilitate these measurements, Bender can manipulate a spine with 0.1 mm accuracy — on par with the thickness of a human hair — and loads as light as a few grams. Running at full capacity, Bender can move 16 kilograms (35 pounds) at speeds up to 14 feet per second and twist or spin up to 615 degrees per second. Additionally, SRL’s robo-mechanics testing is enhanced through use of a technically advanced Optotrak Certus three-dimensional infrared motion tracking system (Figure 3).

Beyond Passive Spine Testing

In the past, spine testing was limited to the domain of single-segment, or “functional spine unit,” tests loading passive spine elements to failure. Bender finally enables study of all the in vitro and theoretical in vivo effects of altered loads on spine structures and allows for active and neural feedback in real time. For example, experiments can now be undertaken to study how loads are altered to the rest of the lumbar spine when a low back fusion is performed, how a spine with scoliosis might affect core muscle functioning or how the cervical spine moves in response to the application of facet pain.
The human spine is a complex system, and SRL is committed to exhaustively using Bender to understand the spine’s intricate motion. Novel projects initiated by staff and SRL researchers are planned in 2011 and beyond, including robo-mechanical studies of instantaneous axis of rotation and helical axis of motion; measurement of the neutral zone, elastic zone and range of motion under flexion-extension, axial rotation and lateral bending; and coupled motion and finite element analysis. With Bender up and running, the SRL is uniquely positioned in the medical research community at the forefront of 21st-century spine research.

Adam Bartsch, PhD, is Director of Cleveland Clinic’s Spine Research Laboratory. Robert McLain, MD, is a spine surgeon in Cleveland Clinic’s Center for Spine Health.

For more information on the Spine Research Laboratory’s robo-mechanical studies, contact Program Manager Brian Perse at 216.363.5741.
Prolonged Opioid Therapy for Spine Pain:
A Clinician’s Perspective

By Edward C. Covington, MD

Long-term opioid therapy for benign pain was once thought inadvisable due to the inevitable development of tolerance, loss of analgesic efficacy, dose escalation and consequent functional impairment. However, more than two decades of journal articles, presentations at national meetings (largely industry-supported) and marketing convinced the public as well as many physicians that Americans were suffering “needless” pain that could be readily relieved if only opioids were judiciously employed.

The result: Physicians in the U.S. have increased opioid prescribing 200-fold over the last 10 years. The adverse consequences of increased availability of pharmaceutical-grade opioids are well-known — deaths from accidental overdose now exceed those from traffic accidents. Teens throw “pharming parties” at which pills from the family medicine cabinet are thrown into a bowl and passed around. Chemical dependency treatment facilities have seen their clientele shift from those suffering from alcohol, heroin and cocaine dependence to oxycodone, hydrocodone, fentanyl and hydromorphone addiction. Entire counties in West Virginia have been devastated by OxyContin abuse, and there are towns in Tennessee that have bus service to pill mills in Florida. Ohio seems to be emerging as a new destination for drugs.

These negative impacts can obscure the benefits of providing analgesia to millions of suffering patients, helping them emerge from invalidism and isolation and resume productive and pleasurable lives.

Opioids May Relieve Pain but Often Fail to Restore Function

We know that pain is a main cause of vocational disability in industrialized countries, that spine pain represents most of this and that in 85 percent of cases no structural explanation is found. We further know that individuals with trivial or no spine pain frequently have substantial degenerative changes on imaging. We conclude that much spine-related pain is probably related as much to neurological sensitization as to peripheral nociception; however, more important, we must conclude that most spine pain-related disability is not an anatomic disability like paralysis and blindness, but is disability due to the fact that activity induces intolerable pain. We hold on to the logically inconsistent position that spine patients (mostly) do not function because they hurt. Opioids relieve the hurt. Yet the fact that the preponderance of controlled studies fail to demonstrate functional improvement in opioid users is not accepted as evidence that the opioids are in fact doing little.

Experts continue to debate whether analgesic tolerance actually develops, despite its being well-demonstrated in rodent studies. Virtually every study of intrathecal opioid analgesia finds that patients have initial excellent results but need to increase the dose and add systemic opioids after a few years. Clinically, we know that almost all noncancer pain responds acutely to parenteral opioids (excepting such conditions as post-stroke or “thalamic” pain and deafferentation pain); yet in chronic use we find that zero percent of our patients have zero pain, often despite marked dose escalation.

These contradictions are rarely mentioned in the literature. Several articles by Jane Ballantyne at Harvard have been enlightening. In essence, Dr. Ballantyne’s reviews confirm that numerous studies clearly demonstrate the benefit of opioids for nonmalignant pain. However, essentially all the studies are conducted with ideal patients and low-dose opioids (less than 200 mg/d oral morphine equivalents) and are of six months’ duration or less. Longer studies are open-label, have high (>50%) dropout rates and show less benefit. Approximately half of the studies show an improvement in function, and none show functional normalization, which arguably should occur if pain is the only reason for impairment.

Controlled Studies vs. Results in Practice

Studies of veterans and of health insurance customers (n = 4 million) demonstrate that physicians in practice are prescribing to the worst candidates, not the best. Those with addiction histories are more likely to be prescribed opioids, more likely to receive schedule II opioids, more likely to receive high doses,
and more likely to receive concomitant benzodiazepines than are pain patients not encumbered by comorbid addictive disorder.

Many clinicians are in a position of providing long-term treatment of poor candidates with high-dose opioids, guided only by short-term studies of low-dose opioids in ideal candidates. Not surprisingly, the results fail to mirror the literature’s predictions of success.

Studies of injured workers demonstrate that a prescription for opioids actually predicts unfavorable outcomes as reflected in return to work, claims settlements and costs. The lack of treatment randomization precludes an unequivocal determination of whether sicker patients receive more opioids, or opioids lead to sicker patients. What is clear is that higher-dose opioids have not restored the patients’ comfort or function.

Our dilemma is that we have poor data to guide us, and our patients require care now. A few guides may help. Young organisms develop opioid tolerance more readily than do old ones, possibly due to variable neuroplasticity. Thus, prescribing chronic opioids to a 70-year-old is a smaller gamble than starting a 24-year-old with lumbago on a course of chronic opioids.

Our inability to predict who will be helped by opioids is balanced by our ability to determine who has been helped and by the literature demonstrating that short-term opioid therapy is low-risk. Many patients can be helped with opioids but only if the physician is meticulous in monitoring progress and is resolute in stopping agents if they fail. One rarely hears of patients continued for years on a failed hypoglycemic agent or antihypertensive, yet our clinics are filled with patients who continue on high doses of opioids despite persistent high pain levels and absence of functional restoration.

**Careful Monitoring Is Key**

Thus, if a patient is started on chronic opioids, at the end of six months there should be subjective (pain, mood, enjoyment of life) and objective (work, recreation, socialization) improvements, all confirmed by a significant other, and absent evidence of addiction or other harm. If opioids have failed to help after this time then they should be discontinued, just like any other failed treatment. Those who prescribe chronic opioids should develop skills in weaning patients from them — a process that is not difficult or dangerous but can be conflictual.

Current literature supports the conclusion that opioids have been grossly oversold, though there are many whose lives are substantially helped by their use. The most important key to effective use is meticulous monitoring of treatment results and prompt elimination of these hazardous substances when benefit is not unequivocal.

Edward C. Covington, MD, is Director of Cleveland Clinic’s Neurological Center for Pain. His specialty interests include chronic pain and pain management. He can be reached at 216.444.8832.

**SUGGESTED READING**


Melzack R. *Scientific American.* 1990;262(2).
Surgery at the Top of the Spine: The Craniocervical Junction

By Ajit A. Krishnaney, MD and Edward C. Benzel, MD

The junction of the skull and the upper cervical spine is associated with extremely complex anatomy that is unlike any other part of the spine. Surgery in a region of such complexity has historically been associated with a relatively high rate of morbidity. Fortunately, recent advances in imaging, instrumentation, intraoperative monitoring, and minimally invasive and microscopic techniques have made surgery at the craniocervical junction safer and more effective.

Anatomy

The anatomic structures of this region are uniquely designed for maximal protection of the lower brain stem and upper spinal cord while simultaneously permitting a significant range of motion. The craniocervical junction is comprised of three bony structures — the skull base (occiput; O), the atlas (C1) and the axis (C2) — and their attendant muscular and ligamentous attachments. C1 is shaped like a ring with large, flat joints, perpendicularly oriented to the long axis of the spine. This configuration allows predominantly for flexion and extension at the skull — C1 joint and rotation at the C1-2 joint. In fact, this joint configuration allows for approximately 60 percent of the flexion/extension and rotational range of motion of the entire cervical spine. A number of ligaments extending from the skull to C1 and C2 and between C1 and C2 provide additional stability. These ligaments include the apical (O-C2), alar (O-C1) and transverse (C1-2) ligaments. Disruption of any of these ligaments may result in instability, necessitating surgical stabilization.

Presentation

Patients with craniocervical junction pathologies may present with neck pain, headaches, cervical deformity or signs and symptoms of spinal cord compression (myelopathy). Neck pain is the most common complaint. Patients may also complain of suboccipital burning or electric shock pain associated with C2 nerve root compression, resulting in an occipital neuralgia-like syndrome. Common neurological complaints may include gait instability, numbness in the hands and feet, loss of fine motor coordination in the hands or lower cranial nerve palsies (swallowing difficulties or aspiration).

Diagnosis

In patients with suspected craniocervical pathology, the diagnostic study of choice is magnetic resonance imaging (MRI). In most cases, MRI without gadolinium enhancement is sufficient. However, if a tumor is suspected the study should be performed with and without gadolinium enhancement.

Computed tomography (CT) is useful for elucidating the bony anatomy of the upper cervical spine and skull base, particularly in cases of trauma where fracture is suspected. It is often used in surgical planning when trying to determine ideal screw placement and may even be used for intraoperative navigation. When paired with myelography, CT imaging may be used in lieu of MRI for patients who are unable to have an MRI.

Plain X-rays have largely been supplanted by CT for the diagnosis and management of craniocervical fractures. X-ray can be used to assess broken or loose hardware in patients who have had prior instrumented fusions. Flexion/extension (dynamic) X-rays may be useful in diagnosing cervical instability.

Surgery

The unique anatomy and multitude of surrounding critical structures can make surgical access to the upper cervical spine and lower skull base quite challenging. Over the years, a number of approaches to this region have been developed. Most facilitate access to either the dorsal elements and posterior spinal cord and brain stem or the ventral bony and neural structures. One approach, pioneered at the Cleveland Clinic, uses a true lateral approach to C1 and C2. This allows access to both the ventral and dorsal aspects of the upper cervical spine at the same time. Newer approaches have also been developed in the last five years utilizing minimally invasive tubular retractor technology. This minimally invasive approach permits access to the dens and the anterior arch of C1 without the need to incise the nasopha-
ryngeal mucosa. Advances in surgical endoscope technology are facilitating access to the craniocervical junction through ever-smaller incisions (Figure 1).

In cases of spinal instability — either traumatic, neoplastic, degenerative or iatrogenic — stabilization and fusion of the craniocervical junction is often required as a stabilizing adjunct to surgical decompression. This is usually accomplished via a midline dorsal approach. In cases where decompression is performed via a ventral or lateral approach, a second incision or staged operation may be necessary. This region is notoriously difficult to stabilize due to the paucity of fixation points. However, the development of newer, more versatile fixation systems has dramatically improved the modern-day surgeon’s ability to fixate the skull and upper cervical spine. Currently, fusion rates with modern hardware at the craniocervical junction rival those at other levels of the spine. It is now possible to compress and distract in multiple planes across the O-C1 and C1-2 joints, thus permitting and facilitating intraoperative reduction of deformity. This was not possible in years past (Figure 2).

Summary

Surgery at the craniocervical junction can be quite challenging due to the unique anatomy of the region. Recent advances in imaging, intraoperative navigation, approaches and instrumentation are making operations in this region safer and resulting in improved outcomes.

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Workers’ Compensation: A Primer for the Spine Care Specialist  

By Daniel Mazanec, MD

Spinal injuries are the most common work-related diagnoses nationally and in the state of Ohio. Lumbar sprain/strain and cervical sprain/strain were the top two lost-time injuries (at least seven consecutive missed work days) in a survey of Ohio workers’ compensation claims from 1996 through 2005. Spine specialists may have varied roles in the medical and surgical management of injured workers, ranging from the physician of record who directs overall care to a more consultative function. A clear understanding of the workers’ compensation insurance program facilitates patient care, may reduce risk of prolonged disability and ensures appropriate reimbursement.

History and Organization

Workers’ compensation is a federally mandated insurance program for injured workers, administered by the individual states. The Ohio Bureau of Workers’ Compensation (BWC), founded in 1912, is the largest exclusively state-operated provider of workers’ compensation insurance in the U.S., with a $24 billion fund. In 2010, the bureau provided coverage to more than 256,000 employers and recorded 116,151 new injury claims paying out almost $1.9 billion in benefits to workers.

Workers’ compensation laws date to the early 20th century and represent, in part, a reaction to the growing numbers of work-related injuries and deaths during the Industrial Revolution. Workers’ compensation insurance was conceived as “no fault,” exempting both employer and employee from blame for injuries “arising out of and in the course of employment.” Under workers’ compensation law, employees relinquish the right to sue the employer for damages in most instances and employers guarantee benefits even if they are not at fault.

Though this system was originally intended as a less contentious solution to a growing problem, the increasing number of nontraumatic “injury” claims in the past 30 years has led in many cases to a confrontational process, with the primary issue being whether the condition is truly related to work activity. For example, an employer may contest whether nontraumatic back pain (“lumbar strain”) is related to work or to household or recreational pursuits. Similarly, in older workers, whether a work injury “aggravated” pre-existing degenerative spinal change is frequently disputed.

The employer’s decision whether to “allow” an injury as work-related is the initial and, often, the most disputed step in the process. In Ohio, the Industrial Commission is responsible for adjudicating contested workers’ compensation claims and other issues.

For allowed diagnoses, workers’ compensation may pay two types of benefits. Medical benefits cover treatment costs and are paid from the date of injury for 90 days. An independent medical examination is required at the end of that period to determine whether further compensation is warranted and medical treatment is appropriate.

In addition, injured workers unable to return immediately to the job are eligible for disability benefits for lost wages:

• In Ohio, an injured worker who loses more than seven days of work receives temporary total disability (TTD) compensation equivalent to 72 percent of salary, up to $751 weekly for 12 weeks, and 66 2/3 percent of wages thereafter. TTD is continued until the worker returns to the job or is deemed maximally medically improved (MMI). A person is considered MMI when his or her condition is well-stabilized and unlikely to change substantially in the next year with or without medical treatment.

• If the injured worker is declared MMI but is unable to perform sustained remunerative employment due to the allowed condition in the claim, permanent total disability may be awarded, payable for life at 66 2/3 percent of prior wages, up to a maximum of $751 weekly.
• If the individual is able to work but has sustained a permanent impairment (residual “damage”), a **percent partial impairment award** may be granted based on an independent medical examination. For certain impairments (amputations, loss of an eye, hearing loss), compensation known as a **scheduled loss** may be provided.

• Workers unable to return to their previous occupation may be eligible for working **wage loss compensation** to offset reduced earnings in a different job.

• For injured workers actively engaged in an approved rehabilitation plan, compensation known as **living maintenance** is available.

**The Treating Physician**

The treating physician (physician of record, or POR) plays the central role in medical management of the injured worker. In addition to establishing the diagnosis, the POR must address the issue of causality, i.e., did the condition arise “out of and in the course of employment”? The physician may be asked to address whether the injury "aggravated" a pre-existing condition, e.g., age-related lumbar spondylosis. In Ohio, aggravation requires new or worsened symptoms from the pre-existing condition as well as an objective diagnostic finding or test result. Injured Ohio workers have the right to choose a POR and the freedom to change physicians any time.

Once the diagnosis has been established and allowed, the POR is responsible for medical management of the injury. For advanced spinal imaging, injection procedures, consultations and surgery, approval of the employer’s BWC-mandated managed care organization (MCO) is required. The POR is expected to communicate regularly with the MCO and the employer about the injured worker’s status, particularly about treatment plans and work capacity. At every clinical visit, the POR should make a determination whether the injured patient may return to work, with or without restrictions. Obtaining a formal job description from the employer is important in making the best decision about return-to-work status.

BWC reimbursement for injury care is for the allowed condition (diagnosis). Management of unrelated conditions (e.g., depression or arthritis) should not be intermingled with management of the work injury. If the treating physician identifies another diagnosis associated with the injury, a formal request is required to add the additional “allowance” to the claim. This request may be contested by the employer, requiring a hearing to resolve the dispute.

Ultimately, it is the responsibility of the treating physician to determine when the injured worker has reached MMI and whether any residual permanent impairment exists. For some patients, a formal functional capacity evaluation is useful in defining these impairments and suggesting appropriate restrictions in the workplace (see page 18). Although transitional work (“light duty”) or reduced weekly hours are sometimes effective strategies to facilitate return to work, the most successful long-term treatment outcomes result from unrestricted return.

**The Consulting Physician**

For many spinal injuries, the spine specialist functions as a consultant rather than a POR. In this capacity, the spine specialist evaluates the patient at the request of the POR and makes recommendations for evaluation or treatment. Requests for additional diagnostic studies, consultations or treatment must be made by the POR. The consulting spine specialist may suggest alternate diagnoses to the treating physician but cannot alter the diagnoses allowed in the claim.

Less commonly, the spine specialist may be asked by the BWC or the employer to perform an independent medical examination. In this case, no doctor-patient relationship exists and the reporting responsibility is to a third party, i.e., the BWC. No medical advice or treatment is offered to the examinee. The examiner is usually asked to address such issues as whether a request for a new diagnosis should be allowed or whether treatment requested by the POR, such as surgery or injections, is reasonable and appropriate for the condition allowed in the claim.

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**SUGGESTED READING**

Assessing Injured Worker Capabilities
With a Functional Capacity Evaluation

By Tagreed Khalaf, MD

Physicians are commonly asked to fill out paperwork regarding patients’ function and ability to work after injury or illness. The need for specific information on individuals’ functional capacities and limitations to facilitate return to work was identified in the 1980s by the workers’ compensation system. Historically, return-to-work decisions had been based on diagnoses and prognoses, without objective measurements. Subsequently, researchers and therapists developed tools to help quantify capabilities. Their work evolved to today’s functional capacity evaluation instruments.

Even with these tools, quantifying function can be a challenging task. Following is a summary of frequently asked questions and answers.

**What is a functional capacity evaluation (FCE)?**

An FCE is a comprehensive battery of performance-based tests used to help identify maximal capability to perform work tasks. It is a test of the whole body and becomes work-oriented when compared with a functional job description.

**Why would one use an FCE?**

An FCE can be used for a variety of reasons. Administered by a specially educated therapist, it can determine a worker’s ability to meet the critical demands of his or her job. Furthermore, an FCE can quantify safe functional abilities and identify when one can return to work, as well as the need for job modifications, ergonomic changes and additional rehabilitation. An FCE can also be used to monitor worker progress throughout a rehabilitative program.

**What are the components of the FCE?**

In practice, there are many FCE systems, but the typical components include a review of patient medical records and history, a physical assessment, therapists’ observations, specific functional testing, and a comparison of testing with job requirements.

Therapists’ observations may include worker effort, cooperation, consistency of performance, pain behaviors, safety and quality of movement. Specific functional testing may vary based on the FCE system used as well as the job description. Typically, this component involves:

- Testing of strength and weight-handling capacity, which may comprise floor-to-waist lift, waist-to-overhead lift, horizontal lift, static and dynamic push/pull, right- and left-hand carry, front carry, and static hand grip and pinch strength
- A postural, positional and repetitive movement test, which may include overhead work without weight, static trunk flexion, repetitive trunk rotation, crawling, kneeling, static crouch and repetitive squatting
- Static postures and ambulatory tasks such as sitting, standing, walking, stair climbing, ladder climbing and dynamic balance
- Upper extremity coordination tests, which may consist of round blocks, nuts and bolts, and peg board

It is important that the therapist’s final report be logical and clear regarding the client’s physical capabilities and limitations as they relate to the critical demands of the job.

**Are there limitations to an FCE?**

Safety and effort need to be evaluated and enforced. Effort may be assessed by monitoring heart rate or evaluating consistency of performance in isometric strength testing. Safety may be assessed by monitoring lifting mechanics and techniques. Testing can also be limited by pain.
Length of testing is another factor to consider because it is variable. Some FCEs take less than two hours to administer, while another type is administered over two days. The shorter FCEs are less likely to include all the physical demand items. An FCE must be able to evaluate endurance, possibly by monitoring heart rate, change in body mechanics and fatigue, because the information obtained is extrapolated to the typical workweek.

Is an FCE reliable?

Reliability refers to consistency in measurement. Inter-rater and intra-rater reliability are purported to be the two most important forms of reliability in FCE testing. Several studies have shown that the FCE has high inter-rater reliability and good intra-rater reliability:

- Inter-rater reliability refers to the ability to achieve similar scores on an evaluation administered by two different evaluators. Inter-rater reliability is important because an FCE may be administered by one therapist prior to treatment and by another therapist after rehabilitation.

- Test-retest, or intra-rate, reliability refers to the stability of a score derived from one FCE to another when administered by the same rater. Variables that may affect this measurement are the time between the two evaluations, the stability of the client’s condition and the treatment received in the interim period.

An FCE is best utilized in combination with a history, physical examination and comparison of the client’s abilities with the demands of the job. An FCE can help objectively identify the patient’s functional abilities, need for job modifications and safe return to work. By contrast, use of the “best guess” method may lead to overestimation and reinjury or to underestimation, and may make it impossible for the employer to accommodate the worker. Accurate work-related functional evaluation performed according to available guidelines will continue to grow in importance.

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iain Kalfas, MD | 216.444.1179

**A prospective, multicenter, double-blind, randomized, placebo-controlled pivotal study of ultrasound therapy as adjunctive therapy for increasing posterolateral fusion success following single-level posterior instrumented lumbar surgery**
Ajit Krishnaney, MD | 216.444.1179

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Spinal Column

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Every life deserves world class care.

Highlighting Laboratory Research and Clinical Advances in Spine Health
(continued from cover)

Another exciting research activity within the CSH and SRL is described by Adam Bartsch, PhD, and Robert McLain, MD, who present a brief overview of robotic testing of the spine and its use in evaluating spinal anatomy, mechanism of spinal injury, the effect of spinal implants on spine biomechanics and many other aspects of spine function. Robotic testing of the spine, although not widely available, provides the ability to obtain exciting in vitro data as well as providing insights into the in vivo spine.

Finally, Edwin Capulong, MD, presents some exciting research efforts into the biomechanics of the golf swing and how both symptomatic and asymptomatic degenerative disc disease may alter the normal swing.

We hope that our readers will enjoy this potpourri of interesting and exciting work being performed in the Center for Spine Health and the Spine Research Laboratory at Cleveland Clinic. We look forward to presenting more exciting developments in fall 2012.

FOR MORE INFORMATION
To learn more about the Center for Spine Health, please contact Dr. Bell at 216.444.8126 or our administrator, Susan Rossi, at 216.444.6890. To refer patients, call 216.636.5860 or toll-free 866.588.2264.

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