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PAPER

PATHOLOGY/BIOLOGY

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Pathologic Evaluation of the Cervical Spine Following Surgical and Chiropractic Interventions

ABSTRACT: When patients die after chiropractic or surgical interventions of the cervical spine, pathologists tasked with the autopsy are frequently overwhelmed by the complicated anatomy, laborious dissections, complex operative procedures and surgical hardware, and the necessity to differentiate artifacts from trauma and disease. However, abundant data can be obtained from careful evaluation of the cervical spine *in situ*; extensive postmortem diagnostic imaging procedures; detailed dissections of the removed, formalin-fixed and decalcified spine; and histology. This study presents a regimented, stepwise approach to the evaluation of the cervical spine in these difficult cases, promotes uniform assessment, facilitates diagnoses, and supports the accumulation of otherwise hard-to-come-by reference material that can be of value in future cases. The resultant detailed autopsy findings may prove useful in the medico-legal death investigation process. Autopsy findings may also be of great value to health care providers involved in quality assurance processes.

KEYWORDS: forensic science, autopsy, neuropathology, neurosurgery, chiropractic, cervical spine

Individuals with abnormalities of the cervical spine may be entirely asymptomatic; alternatively, they may have varyingly severe functional abnormalities that interfere with their abilities to challenge activities of daily living. *Chiropractors* assess patients with neck pain and headaches and when appropriate, utilize external modalities of care such as "neck adjustments." Although symptomatic complications are reportedly frequent following neck adjustments (1,2), life-threatening complications are considered rare (3,4), but potentially underreported (5). *Neurosurgeons* tasked with the treatment of patients with derangements of the cervical spine have a difficult job, as they are forced to meticulously evaluate form and function, then operate within small fields that contain a disproportionately large number of critical anatomical structures. Despite these challenges, operative mortality remains decidedly low at <1% (6). When death occurs during or following surgery or when chiropractic neck manipulation occurred at or around the time of death, judicial death investigation is frequent. When an autopsy is not mandated by law under such circumstances, it is common for family members to request an academic autopsy.

Evaluation of decedents with known or suspected cervical spine pathology, including especially those having undergone recent neurosurgical intervention(s), and those with recent chiropractic manipulation, can be harrowing for pathologists. Not only are pathologists responsible for all of the tasks intrinsic to typical autopsies, but they must also have a working knowledge of cervical spine anatomy including both the chondro-osseous elements and neurovascular structures. Furthermore, they need an understanding of the common neurosurgical techniques utilized in the neck and must differentiate trauma and disease from artifacts of surgery. Finally, pathologists must be able to perform the laborious dissections necessitated by "spine cases," make observations, produce extensive documentation, and formulate accurate diagnoses.

This onerous set of tasks can induce stress in even the most experienced pathologists; a less-experienced pathologist may be overwhelmed by the request to perform such an autopsy. Sometimes, pathologists erroneously claim that a detailed examination is not possible and that antemortem radiographic studies are the only or best means of evaluating the neck. Other times, autopsy of the cervical spine is reduced to a cursory *in situ* observation. Some pathologists will extract the spinal cord from the spinal canal or remove vertebral arterial segments from the transverse processes, and then claim success in assessing the spine in a complicated case. Ultimately, the most thorough examinations produce the most detailed results, and it is only methodical evaluation of all neck compartments that will allow for the most accurate diagnoses. Following the work of Berzlanovich et al. (7), Vanezis (8), and others (9,10), we recommend the following considerations and approach.

Cervical Spine Anatomy

The critical neurovascular anatomy of the cervical spine is protected by an osseous framework—the vertebrae—and extensive musculature and fascia that surround and invest the neck. Detailed reviews of cervical spine anatomy can be found in treatises of human anatomy and neurosurgery (11,12). We find it easiest to view the spine in a compartmentalized fashion: musculature and fascia, chondro-osseous skeleton, the spinal cord and its coverings, the cervical spinal nerve roots, and the vasculature. The cervical spine itself is generally regarded as being composed of those subcutaneous structures posterior to the prevertebral fascia. Much of the musculature of the anterior neck is external to the cervical spine

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proper and is instead more appropriately categorized through its intimate relationship with the laryngohyoid complex. A detailed knowledge of anatomic structures anterior to the prevertebral fascia is required for the autopsy of a decedent who underwent spinal surgical interventions performed through an anterior approach (13).

Pathologic Evaluation of the Cervical Spine

Preautopsy Considerations

Prior to evaluation of the decedent's remains, it is important to review all available historical data including especially operative reports and the results of diagnostic imaging studies. It may be appropriate to speak directly with health care providers to gain information that is not obvious from a review of the records. For example, a surgeon may attempt to insert a surgical screw into one location, abort the attempt, and then reposition the screw elsewhere leaving behind extensive artifacts that might not be described in the surgical record. It is also important to speak with the surgeon or operating room nurses/technicians to gain access to the special screwdrivers and other equipment that might be necessary at the time of autopsy to remove neurosurgical devices. Such tools might be necessary for the removal of halo cervical traction systems prior to commencement of the autopsy.

The available information will also indicate the necessity for preautopsy radiography. Although uncommon, it may be appropriate to obtain plain film radiographs of the skull base and spine *in situ* (prior to dissection). Such films can be of importance in circumstances such as when (i) antemortem radiographs were not obtained, (ii) an interval change is suspected between surgery and autopsy and comparison with earlier radiologic findings is suspected to be revealing, and (iii) vertebral dislocations or disassociations are suspected or known clinically and thus preautopsy radiographs will be useful to document spatial abnormalities. Preautopsy magnetic resonance imaging (MRI) and computed tomography (CT) scans may also be appropriate if such resources are available; however, their use and subsequent interpretation will be influenced by the nature of any indwelling metallic surgical devices, which may impart severe artifacts.

It can be very difficult to properly position the body of a deceased person for radiography; indwelling cervical hardware can exacerbate this issue. For example, it is uncommon to successfully obtain *in situ* odontoid and suboccipital views. When technical limitations prevail, anteroposterior and lateral views may suffice.

Although significant advances have been made in the area of postmortem imaging, we feel that such tools are useful adjuncts, and not replacements, of a thoughtful and thorough autopsy.

Evaluation of the Anterior Neck

After external examination and evaluation of the thoracoabdominal contents, the brain should be removed in the typical fashion. Although it is always ideal to decompress and drain the vasculature of the head and neck prior to anterior neck dissection, this may be practically difficult or impossible if the spine is surgically fused, and especially if the spine has been fused to the cranium. A thorough anterior neck dissection should be performed in accordance with standard teaching in forensic pathology textbooks (14) and scholarly articles (15). In cases where the spine has been surgically accessed through an anterior approach, it may be appropriate to modify this dissection to address issues specific to that case. For example, when intra- or postoperative bleeding was problematic, careful evaluation of major and minor vasculature is in order and can be accomplished through careful dissection, or if available, radiographically with injection of contrast material into isolated vascular segments.

After stepwise evaluation of anterior neck structures, the tongue, hyoid bone, larynx, and trachea should be removed and assessed as per routine. The contents of the bilateral carotid sheaths may require detailed evaluation, and prior to dissection or manipulation, the pathologist should consider the role (if any) of perfusion studies for carotid patency, or the injection of contrast material for radiographic studies. Both carotid arteries must then be stripped from the spine to the level of the skull base and elevated anteriorly. The external carotid artery may also be tied as an aid to the embalmer.

The intrathoracic extracervical (V1) segment of the bilateral vertebral arteries must also be identified, ideally prior to removal of the aortic and its main branches. Both V1 segments should be evaluated *in situ*, removed in their entirety, and formalin-fixed for histologic studies.

Evaluation of the Posterior Neck

After completion of anterior neck evaluation, the body should be turned prone. Care should be taken to protect the face during turning (particularly with obese patients), and the face should be supported on a soft surface during the entire dissection. Following careful assessment of the skin of the posterior scalp, posterolateral aspects of the neck, and the upper back, an inverted "T"-shaped incision should be made, which extends inferior from the coronal scalp incision to approximately the second thoracic vertebra (T2), and across both shoulder blades. The skin and subcuticular adipose tissue should be reflected laterally. A detailed evaluation of the musculature and fascia of the posterolateral aspects of the neck should be performed in accordance with standard teaching in forensic pathology textbooks (14) and scholarly articles (16).

Once the suboccipital triangle has been exposed (Fig. 1), the pathologist must pause and proceed more cautiously as the extracervical, extracranial (V3) segments of the bilateral vertebral arteries rest immediately below (Fig. 2), and can be easily damaged during dissection. Incising the rectus captis posterior major muscle and the obliquus capitis inferior muscle bellies at the spinous process of the second cervical vertebra (C2) allows both muscles to be reflected laterally, and then when incised at the occipital bone and lateral mass of the first cervical vertebra (C1), completely removed. Similarly, the rectus capitis posterior minor muscle can be incised and removed from both the spinous process of C1 and the skull base, and the obliquus capitis superior muscle can be incised and removed from the lateral mass of C1 and the skull base. This will allow for visualization and evaluation of the entire length of V3.

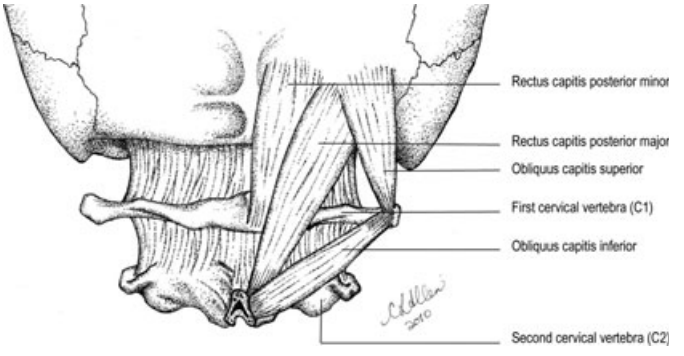

FIG. 1—*Diagram of the muscular anatomy of the suboccipital region including the suboccipital triangle, which is drawn by Carrie Allen and reproduced with permission of Academic Forensic Pathology Incorporated.*

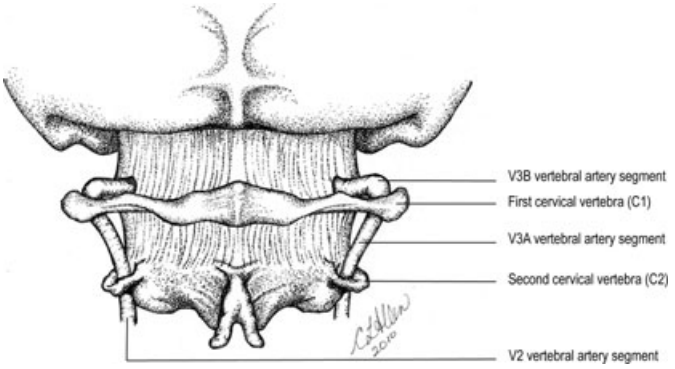

FIG. 2—*Diagram of the distal V2, V3a, and V3b segments of the bilateral vertebral arteries. The posterior arch of C1 serves as the marker between V3a (below) and V3b (above). Although drawn vertically, V3a commonly takes a serpiginous course. Notice the harshly horizontal nature of V3b. If this vascular segment is not removed prior to serial sectioning of the spine, it will be cut longitudinally—this can bring about significant limitations to further studies, analyses, and diagnoses. This figure is drawn by Carrie Allen and reproduced with permission of Academic Forensic Pathology Incorporated.*

The posterior arch of C1 serves as a marking point between the V3a and V3b segments. The V3a segment is relatively unprotected as it courses superiorly (generally vertically but oftentimes serpiginously) between the lateral masses of C2 and C1. The V3b segment is protected only by soft tissues as it takes a harshly horizontal course along the posterolateral arch of C1 before perforating the atlanto-occipital membrane and entering the skull as the V4 (intracranial) segment.

Given the frequently serpiginous nature of V3a and the predominantly horizontal nature of V3b, we highly recommend excising both of these arterial segments at this point in the autopsy, and submitting them for serial sectioning and histologic evaluation following formalin fixation. Should the pathologist forget to excise these vascular segments prior to serial sectioning of the decalcified spine, they may be damaged in a fashion that impacts or prevents further evaluation and interpretation. Given the anatomically vulnerable nature of these segments (9,17), the introduction of dissection artifacts may have negative consequences for the whole case (Fig. 3). Careful blunt dissection with scissor tips or blunt forceps will facilitate exposure of the V3a and V3b vascular segments. Upon visualization of the entire lengths of these segments, we recommend using a sharp scalpel to carefully excise the vessel, making incisions perpendicular to the long axis.

It is important that the pathologist make a careful *in situ* evaluation of the spine, paying particularly close attention to the spatial relationships between the individual vertebrae and their articulations, especially between the occipital bone and C1, and the first two cervical vertebrae. Removal of the cervical spine will not create disarticulations where they did not exist; however, pathologically altered vertebral relationships can be enhanced, especially when fractures are present. Conversely, disarticulations may be reduced with handling leading to under-appreciation or omission of potentially critical findings.

Removal of Indwelling Surgical Hardware

Generally speaking, we do not recommend removal of any indwelling neurosurgical hardware until the spine has been removed, radiographed, formalin-fixed, and decalcified. This minimizes the creation of artifacts and helps to preserve the relationships between the hardware and neighboring anatomic structures (Fig. 4).

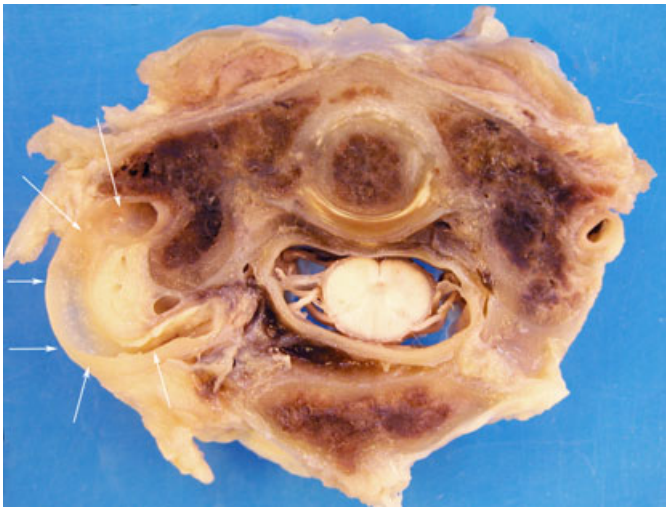

FIG. 3—*Oblique axial section through the skull base and superficial—most part of the posterior arch of C1. (The dens is in the midline upper third of the image.) The left V3b vertebral arterial segment (white arrows) was not removed prior to serial sectioning of the spine. Consequently, it has been cut longitudinally, complicating macroscopic and histologic studies. Also, although this arterial segment is incised in the same plane along its length, this is accidental and difficult to replicate given the winding, somewhat unpredictable course often taken by the arteries at this level.*

Removal of the Spine

The musculature and other soft tissues invested into the lateral aspects of the spine are incised so that both hands can be inserted into the neck and actually encircle the spine (i.e., the fingertips should at least touch anteriorly, and the thumbs should touch posteriorly). A typical oscillating saw is used to cut a "square" around

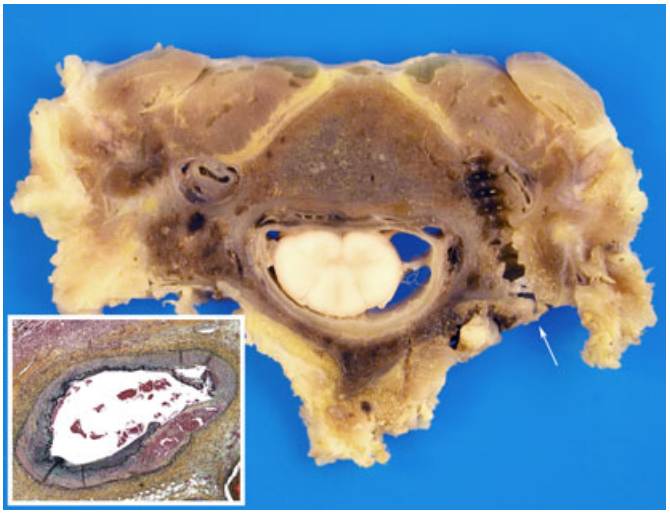

FIG. 4—*Axial section through the inferior third of the fourth cervical vertebra. This patient had undergone occipitocervical fusion with an extended-occipital-plate cervical rod system with numerous transarticular screws. Intraoperatively, there was the suspicion of iatrogenic left V2 segment vertebral artery injury. An intraoperative angiogram was interpreted as normal, and a comment was made about the congenitally small nature of the right V2 segment. In the early postoperative period, the patient had cerebellar symptoms and died shortly thereafter. Cervical spine studies demonstrated that both right and left V2 segments were of nearly the same size, but that the right was focally severely compressed by a transarticular surgical screw placed intraoperatively (white arrow). Histology of the affected arterial segment showed focal mural hemorrhage (dissection) immediately distal to the compression site (4× magnification, Musto stain).*

the foramen magnum thus freeing the central skull base and spine from the rest of the skull. While the saw is being operated in the region of the skull base, ensure that the common carotid arteries are being pulled anteroinferiorly and away from the saw's blade. Although the saw will cut the internal carotid arteries, this is inconsequential from an embalming perspective. However, it is critical that the external carotid arteries be protected. It is important that the operator of the saw be cognizant of the total width of C1 as it underlies the skull; sawing too narrowly around the foramen magnum will result in the damage or loss of the C1 transverse processes with possible resultant loss of critical data.

If the thoracolumbar spinal cord is also to be examined, it is advantageous to expose and remove the cord in these regions prior to transection of the thoracic spine. The spinal cord can be accessed either posteriorly or anteriorly, depending on the needs of the individual case. The thoracolumbar spinal cord should be formalin-fixed and examined separately.

Once the spine is free from the skull base, cut across and through the T1–T2 intervertebral disk with the saw. Divide any remaining soft tissues with a scalpel; the spine should now be free.

It is important that the cervical spine is freed from the body first from the skull and then from the thoracic spine. If these processes are inverted, dissection of the spine from the skull base becomes very laborious.

Summary photographs from key components of the dissection are featured in Fig. 5*A–P*.

Formalin Fixation and Decalcification

Place the spine in 10% neutral buffered formalin. The spines of infants and young children will require at least 1 week of fixation, and the spines of adults will require at least 2 weeks (oftentimes 4 weeks). Once the specimen is fixed, take at least plane film radiographs in the anteroposterior and lateral planes if they have not been obtained preautopsy. If CT is available, high-resolution, thin-cut images could be obtained allowing for further evaluation and possible three-dimensional reconstructions (Fig. 6). As a general rule, MRI is a poor modality for bone and is instead preferred for soft tissues and neurovascular anatomy. Depending on the type and metallic composition of indwelling hardware, artifacts may be significant with both CT and MR scanning.

After all radiographic images have been obtained, the spine should be placed into a decalcification solution. We have found 17–20% formic acid to be a safe, effective, and inexpensive way to decalcify

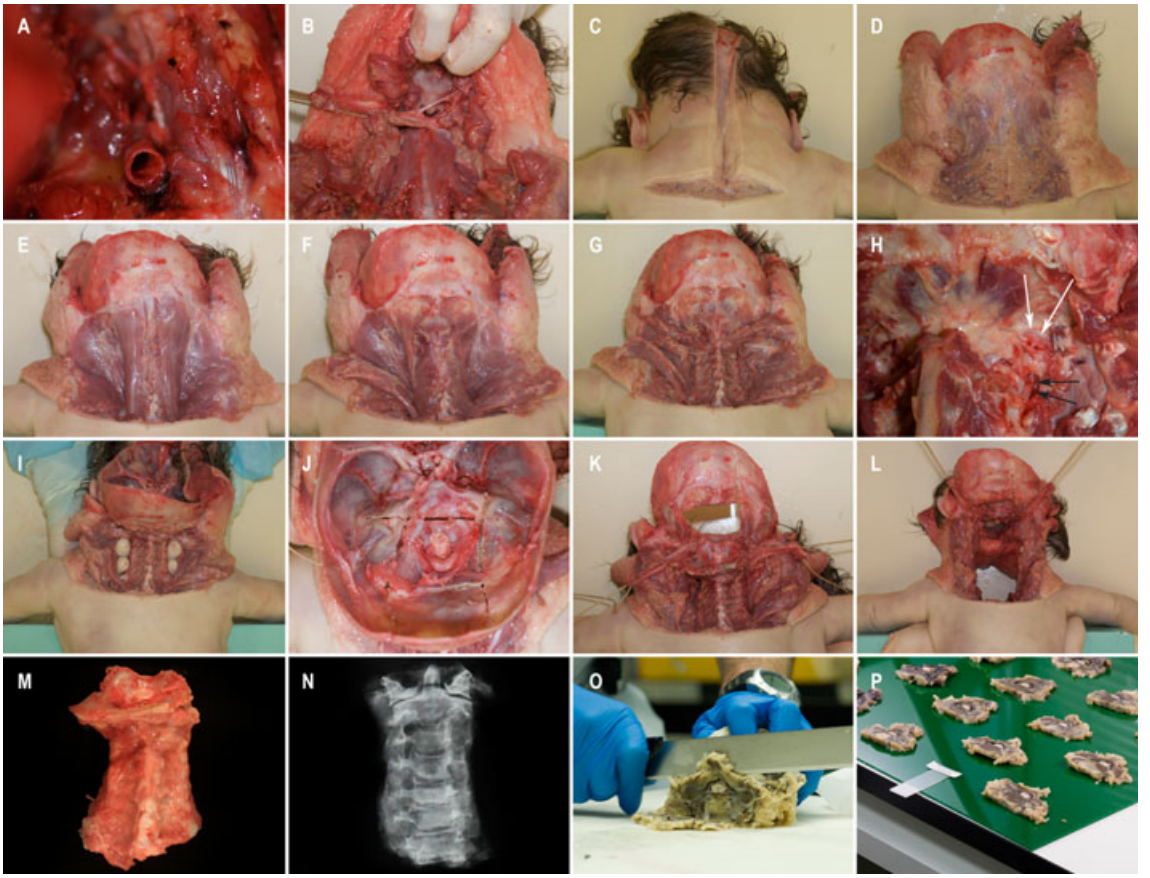

FIG. 5—*Stepwise photographic representation of the major dissection steps. (A) The cut end of the right V1 segment of the vertebral artery immediately distal to the right subclavian artery (not present in photo). The entire length of the vessel (until the level of the vertebral bodies) needs to be resected on each side of the neck. In (B), the common, internal and external segments of the left carotid artery are isolated and ligated (to assist the embalmer). (C) The typical inverted "T"-shaped incision used to connect the vertex scalp incision to the upper back, and in (D), the skin and subcuticular soft tissues are elevated from the underlying fascia and musculature. (E–G) The evaluation of the superficial, intermediate, and deep musculature of the posterior neck musculature (to the level of the suboccipital triangle). After removal of the muscles comprising the suboccipital triangle (H), the V3A (black arrows) and V3B (white arrows) segments are carefully isolated and then excised. After incisions and blunt dissection, the cervical spine and most of the skull base are now free of soft tissue connections (I). In (J), a square has been sawed around the foramen magnum using an oscillating saw. Using a scalpel, the cervical spine is freed from remaining soft tissue connects (K), and with deliberate retraction of the bilateral carotid arteries, then removed from the body (L, M). The excised spine should be formalin-fixed and then radiographed prior to decalcification (N). Following decalcification, the spine should be serially sectioned into thin slices (O; usually no more than 3 mm each), laid out in anatomic sequence (P), and then photographed.*

FIG. 6—*Three-dimensional digital model of extracted cervical spine, oblique left lateral view (high-resolution computed tomography scan). Such models can be of value for assessing bony anatomy in all planes and for demonstration of injuries in the courtroom or other settings where autopsy photographs might be considered "inflammatory."*

cervical spines. Infants and young children require 1–2 weeks of decalcification, and adults require at least 4 weeks. The simplest way to assess readiness for dissection is to hold the spine, gently flex it, and apply pressure with your thumb onto the body of a mid-cervical vertebra. If the spine flexes slightly, and you are able to depress a vertebral body by a few millimeters, it is ready to serially section.

Evaluation of the Decalcified Spine

Indwelling surgical hardware must first be removed. Stepwise photography (Fig. 7*A–D*), usually with assistance, will simplify documentation.

Starting at the skull base and working inferiorly, using a rigid knife, make long parallel incisions in an axial plane; individual sections should be no more than 3 mm thick (Fig. 5*O*). Continue inferiorly until the entire specimen has been sectioned. Layout sections in the order in which they were removed (Fig. 5*P*). It is now possible to evaluate all remaining compartments of the spine including the prevertebral fascia, the chondro-osseous skeleton, the intracervical (V2) segment of the bilateral vertebral arteries, the spinal cord and nerves, and the relationship of these anatomic structures to any neurosurgical interventions. Knowledge of vertebral anatomy will permit differentiation among the various cervical levels. Regional pathology will be readily identified with this technique.

Photography

Photograph every section of the spine individually. This permits further detailed evaluation at a later date.

Histology

Despite the use of decalcification solution, gentle formic acid 17–20% facilitates the production of high-quality histologic slides. In cases with neurosurgical intervention, we recommend sections of the operative site, the spinal cord at upper, mid, and lower cervical levels, at least one representative section of unremarkable-appearing vertebral artery, and any obvious or suspected pathology. In chiropractic neck manipulation cases, we recommend sections of the spinal cord at upper, mid, and lower cervical levels, of the bilateral vertebral arteries at all V1–V4 levels, and any obvious or suspected pathology.

Synthesis and Reporting

The report should clearly document findings from all components of the evaluation. Synoptic-type reports can be useful in that they ensure routine reporting of findings from all studies and all anatomic

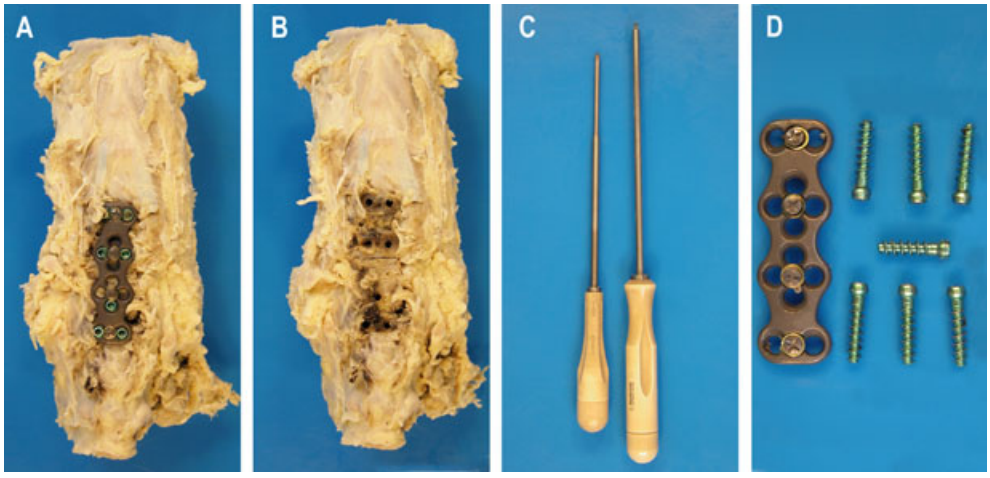

FIG. 7—*Removal of indwelling surgical devices will often require special tools that need to be obtained directly from operating room staff, or from the device manufacturer. In this example, a 55-year-old man died following elective anterior cervicectomy and disk fusion (ACDF) for degenerative disk disease-associated neck pain and upper extremity paresthesia. In the early postoperative period he developed quadraplegia, and then died. Expanding spinal epidural hematoma underlying the operative site was suspected clinically and diagnosed pathologically. (A) The anterior aspect of the extracted spine prior to removal of the metallic plate. (B) The same view following removal of the plate. (C) The two specialized screw drivers that were required to remove the seven screws, which held the plate in place (D).*

compartments (Table 1); they also promote familiarity with the end users of your reports. Diagnoses based on the careful integration of data from all elements of the examination will be the most accurate.

Additional Rationale for Utilizing this Procedure

Deaths associated with chiropractic manipulation (and other forms of "excessive neck movement") are most commonly due to vertebral artery dissection with subsequent intracranial hemorrhage, and vertebrobasilar distribution cerebral infarct following vertebral artery thrombosis (18–23). However, the differential diagnosis of these two common pathologies is broad (24), and pathologists must consider that recent chiropractic manipulation might be entirely coincidental and not causative.

Currently, many pathologists use one or two "standard" techniques for evaluating the vertebral arteries. Some pathologists choose to perfuse the vertebral arteries with radio-opaque contrast material to identify vascular occlusion or rupture. Unfortunately, this technique alone is inadequate as the etiology of stenoses and occlusions cannot be determined. Furthermore, as the etiology of a dissection with or without vascular rupture cannot be determined, practitioners may erroneously conclude that contemporaneous spine surgery or neck manipulation caused the vascular pathology when in fact, for example, the dissection commenced in a V1 segment and was because of atherosclerotic plaque rupture or vasculitis.

Alternatively, pathologists might remove the vertebral arteries along their entire lengths, or segmentally, by removing the vertebral transverse processes. Although this permits direct visualization of vessels and histologic evaluation, in the context of certain neurosurgical procedures this dissection is destructive and limits the evaluation and documentation of the surgical site and its approaches. Furthermore, by destroying the anatomy of the transverse processes, critical evidence can be lost including the relationship of the vessels to circumferential foraminal hematomas, vertebral foraminal spondylosis, and other findings that can significantly impact a case—changing both cause and manner of death. This technique is also frequently associated with operator error—as most pathologists infrequently or rarely evaluate vertebral arteries, they have difficulty locating them while sawing away at the transverse processes and inadvertently damage or destroy segments.

TABLE 1—*Sample synoptic report.*

Macroscopic evaluation
General observations
Material available for examination
Spinal articulations
Posterior longitudinal ligament
Atlanto-occipital membrane
Evidence of surgical intervention
Perispinal soft tissues
Prevertebral fascia
Anterior neck musculature
Posterior neck musculature
Chondro-osseous components of the spine
Basi-occiput
Vertebral bodies
Intervertebral disks
Cervical spinal cord and the spinal canal
Epidural space
Subdural space
Subarachnoid space
Spinal cord
Cervical spinal nerve roots and the dorsal root ganglia
Vertebral artery segments
V1
V2
V3a
V3b
V4
Postmortem artifacts
Radiologic evaluation
Microscopic evaluation
Perispinal soft tissues
Chondro-osseous components of the spine
Spinal cord and the spinal canal
Cervical spinal nerve roots and the dorsal root ganglia
Vertebral arteries
Surgical artifacts
Postmortem artifacts
Summary
Diagnosis

Practical Concerns

Mutilation

Critics of this technique report that it mutilates the human body. All autopsy dissections could be considered mutilating. When done as described, this technique does not change the appearance of the decedent, nor does it impact embalming. Our experience with more than 100 cases of removing the spine of infants, children, and adults has not yielded a single complaint from funeral homes, nor from family members. Some funeral homes prefer that autopsy staff stabilize the head with a wooden dowel or similar device; others prefer no cosmetic intervention. It may be appropriate to discuss this issue directly with funeral homes with which you have regular interactions.

Consultation with the Surgeon

It is not possible for forensic pathologists to know every nuance of a surgical procedure, nor is it always possible to glean a complete understanding of a patient's history and surgical course from simple chart review. Therefore, it is advisable for pathologists to consult the primary care provider and consultants involved in the care of a patient who died and requires autopsy with cervical spine studies. However, oftentimes these cases are controversial and investigative findings may have medico-legal consequences for surgeons. If the surgeon is allowed to observe (or worse participate) in the autopsy or subsequent spine studies, the pathologist is open to criticism of personal or professional bias toward the surgeon (who may be under accusation of malpractice). When neurosurgeon presence at the time of autopsy or spine evaluation is considered important, it can be useful to have an outside (third party) neurosurgeon present to provide consultation. When such an opportunity does not exist, discussion with the legal counsel at your institution may be appropriate prior to permitting surgeon attendance.

Face Dissections

Our method allows the head to remain attached to the torso by skin and soft tissues of the lateral and posterior aspects of the neck. However, should a thorough facial dissection be performed, this skin and soft tissues are separated from the torso causing complete decapitation. Thus, we caution pathologists to perform either spine resection or face dissection giving priority to the technique felt to have the greatest significance to that particular case.

Conclusion

Death following neurosurgical and chiropractic interventions of the cervical spine can be challenging to investigate. The difficulties

associated with evaluating such complex cases can be minimized by having a detailed working knowledge of cervical spine anatomy, by having a systematic approach to cervical spine evaluation, by utilizing as many modalities of investigation as are available in one's own institution, and by producing reports and diagnoses that are based on the available data set. The entire cervical spine must be carefully evaluated before pathologists are able to comment on the significance of findings. For example, the discovery that a surgical screw occludes the mid-left vertebral artery might be inconsequential if that vessel was occluded distal to the screw by atherosclerotic plaque or if the left vertebral artery was naturally diminutive compared with the dominant right vertebral artery. Another example would be the discovery of posterior fossa subarachnoid hemorrhage with radiographic evidence of right vertebral artery rupture; although both are factually correct, the underlying cause is missed if the pathologist does not identify the ulcerated and dissected atherosclerotic plaque or vasculitis in the proximal vertebral artery, which leads to the dissection, rupture, and subarachnoid hemorrhage. If such a case were to be temporally associated with neurosurgery or chiropractic manipulation, the consequences of pathologic misdiagnosis could be adverse.

Acknowledgments

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