C1-2 Puncture: A safe, efficacious, and potentially underutilized technique

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Purpose

- C1-2 puncture for CSF collection or contrast injection is perceived to be more dangerous and difficult to perform than lumbar puncture, especially amongst younger radiologists who have little exposure to and training in the technique.

- There are relatively few reports of complications with lasting sequelae, all relating to puncture under fluoroscopic guidance, and most involving injection of metrizamide into the spinal cord.

- Certain patient populations require the C1-2 approach and it may be safer and more comfortable than the lumbar approach in others.

Our purpose is to demystify the C1-2 puncture and justify the assertion that it should be more frequently utilized, for the benefit of patients, and in order to produce new radiologists capable of safely performing this important procedure.
Approach

- Briefly review the history of C1-2 puncture and current modes of practice
- Outline indications and contraindications
- Describe the technique using fluoroscopic and CT guidance
- Review the literature describing complications of C1-2 puncture and discuss relevant vascular variants
- Consider patient populations who require a cervical approach or would benefit from cervical puncture over lumbar approach
Introduction

- Lateral C1-2 puncture for CSF collection or cervical myelography is a safe and useful alternative to lumbar puncture

- The cervical approach is required in certain patient populations, including those who must remain supine, those with contraindications to lumbar approach, and in patients with myelographic block

- Given the necessity of cervical puncture in certain cases, neuroradiology trainees must have adequate exposure and practice to safely and comfortably perform this procedure

- While considered a safe procedure, C1-2 puncture is infrequently performed
  - In a 2009 study, Yousem et al. polled neuroradiology program directors and found that 14.3% (12/85) had not performed a C1-2 puncture for cervical myelography at their institution in the previous year
  - 47.6% (40/85) performed 1-5 per year
  - 73% (59/81) stated that they trained fellows to perform the procedure
  - Given the few cervical punctures performed, it may be that fellows do not perform an adequate number to become competent and comfortable with this procedure
Introduction

- There have been scattered case reports and small series describing the complications related to this approach: the overall number of complications relative to total cervical punctures performed is small\(^2-7\)

- With the exception of one report of 3 patients\(^8\), the literature describing the technique and complications is based on needle insertion under fluoroscopic guidance

- The increasing use of CT-guidance in radiology procedures has further decreased the risk of C1-2 puncture

- As in all radiology procedures, thoughtful preparation, careful attention to technique, and solid knowledge of relevant anatomy and variants minimizes potential complications
C1-2 approach: History

- 1920: CSF sampled by cisternal puncture
  - Neck flexed
  - Needle blindly inserted in the posterior midline below the occiput
  - Complications were not uncommon

- 1968: Neurosurgeons Kelley and Alexander described a lateral C1-2 approach for myelography as a safer, more easily performed route to the cervical subarachnoid space
  - They utilized an 18g spinal needle and directed it anteriorly toward the ventral subarachnoid space at the C1-2 level

- 1969: Radiologists used lateral C1-2 puncture for “painless gas myelography”, the alternative to Pantopaque myelography
C1-2 approach: History

- Historically, three different approaches have been used:
  - Oblique anterior approach with the needle directed to the anterior 1/3 of the canal, lateral to the cord
  - Lateral approach with needle directed toward the cord to access the lateral subarachnoid space
  - Lateral approach with needle directed toward the posterior 1/3 of the canal

- The third approach is used today: it is the safest trajectory in the presence of unsuspected variant vertebral artery anatomy (present in 1-2% of individuals³)

Orrison et al. Radiology 1983¹¹
The ubiquitous use of MRI to evaluate spinal pathology has markedly decreased the use of contrast myelography.

However, some patients cannot have an MR or will have suboptimal images:
- MR incompatible medical devices
- Claustrophobia
- Spinal hardware

In addition, some neurosurgeons prefer myelograms or a combination of MRI and myelogram for surgical planning.

Collection of CSF for diagnosis or access for intrathecal chemotherapy injection remains a common procedure performed with imaging guidance.

For these reasons, spinal puncture, whether lumbar or cervical, is a necessary skill for the radiologist, and competence in both approaches is required.
C1-2 approach: Indications

- Failed or unsafe lumbar puncture
  - Skin or subcutaneous infection in the lumbar region
  - Arachnoiditis
  - Spinal dysraphism, tethered cord, low-lying conus
  - Congenitally narrow canal
  - Severe degenerative changes, stenosis
  - Spinal fusion, hardware
  - Detection of malignant cells (failed by lumbar puncture)

- Spinal block
  - Myelogram to delineate the superior aspect of block
  - Safe CSF collection in the setting of block

- Evaluation for lumbar CSF leak

- Cervical myelography
  - Especially in the case of thoracic kyphosis where lumbar injection of contrast may not easily reach cervical region
C1-2 Approach: Contraindications

- Chiari malformation
- Mass at C1-2 level
- Acquired or congenital stenosis at C1-2
- Ectatic vertebral arteries which extend to posterior 1/3 of canal (1-2%)
  - May proceed cautiously if unilateral
- PICA caudal loop extending to C1-2 level or PICA origin below C1 (extremely rare)
- Contraindications common to cervical and lumbar puncture
  - Increased intracranial pressure with impending herniation
  - Coagulopathy, platelets less than 50,000 (relative contraindication)
C1-2 approach: Technique

- Prior imaging should be evaluated for Chiari malformation, mass, narrowing at the C1-2 level, anomalous course of the vertebral arteries or PICA.
- Whether using fluoroscopic or CT guidance, the posterior 1/3 of the canal at the C1-2 level is the target for needle placement.
- The patient can be placed in any position (supine, prone, decubitus, oblique).
- Fluoroscopic guidance has the advantages of speed and real time visualization of needle progress.
- CT guidance allows for clear visualization of the target and spinal cord.
C1-2 approach: Technique

- The skin entry site is approximately 1cm posterior and inferior to the mastoid process

This patient is in prone position on the CT gantry. The needle has been placed under CT guidance. After needle tip location was confirmed with good flow of CSF, tubing was connected for fluid collection.
C1-2 approach: Technique

Sagittal, axial, and coronal CTA images with reference lines at the C1-2 target level and location in the dorsal subarachnoid space. Note the typical location of the vertebral arteries at this level, far from the target. No vessels are seen along the anticipated course of the needle (yellow star and arrows).
Technique

Sagittal and axial T2-W images with reference line drawn at the C1-2 puncture level.

The axial image shows that there is nearly 6mm of dorsal subarachnoid space at the target level.
Technique: Fluoroscopic guidance

- The patient is prepared in the same manner as for lumbar puncture with sterilization of the skin and draping.
- With the patient in a comfortable position, a scout image is obtained.
  - A true lateral projection is vital.
  - The C1 arch should appear as a single line, endplates of C2-3 should overlap.
- Divide the canal into thirds: the needle target is in the **posterior 1/3**.
- Steadily advance the needle, removing the stylet to check for CSF as needed.
- On the AP projection the needle may reach the midline before CSF is obtained.
Technique: Fluoroscopic guidance

- The needle may “tent” the tough cervical dura before penetration.
- The needle should be advanced with bevel oriented posteriorly until the dura is punctured, then turned 90 - 180 degrees for ease of CSF collection.
- If injecting contrast, watch contrast diffuse freely from needle tip:
  - If contrast pools, the needle may be subdural or epidural.
  - If linear contrast is seen in the central canal, consider injection into a syrinx.
- Return the stylet and reposition.
- Flow of arterial blood from the hub, pain or paresthesias in the extremities, or Lhermitte sign indicate that the procedure should be terminated.
Case: Fluoroscopic guidance

65-year-old man with altered mental status.

The patient had a known history of severe arachnoiditis as well as extensive spinal hardware and bone graft. Cervical puncture was performed for CSF collection.

Note the proper position of the needle in the posterior 1/3 of the canal.
Technique: CT guidance

- After patient positioning on the CT gantry, a grid is placed on the neck for puncture site localization, identical to a CT guided biopsy.

- After marking the desired entry site, the skin is sterilized and the patient is draped.

- Measuring the distance from skin surface to subarachnoid space target on the initial image can greatly aid in estimation of needle depth, decreasing the number of times CT confirmation or stylet removal must be performed.
Case: CT guidance

35-year-old woman with suspected meningitis. Spinal dysraphism and surgical changes prohibited lumbar approach for CSF collection.

The 22g spinal needle was steadily advanced until the operator detected a subtle change in pressure/texture. The CT images confirmed accurate trajectory of the needle toward the dorsal subarachnoid space in the posterior 1/3 of the canal. The needle was advanced several millimeters, the stylet was removed, and clear CSF flowed from the hub.
Case: CT guidance

18-year-old woman with history of candida spinal meningitis with extensive adhesions, loculated collections, arachnoiditis, and near complete spinal block.

A lumbar puncture was attempted in order to fill the distal thecal sac, but only trace contrast could be injected amidst the clumped nerve roots. Cervical puncture and contrast injection was performed to assess flow above the block.

Note contrast in the dependent subarachnoid space at the C1-2 level (patient had to be placed in decubitus position)
C1-2 approach: Complications

- Complications of C1-2 puncture are rare with proper adherence to technique, solid knowledge of anatomy and relevant variants, and adequate training.

- Most complications and adverse events related to cervical puncture are identical to those of lumbar puncture:
  - Pain
  - Anxiety
  - Bleeding
  - Infection
  - Contrast allergy (in the setting of myelography)
  - Subarachnoid hemorrhage (exceedingly rare)
  - Epidural or subdural hemorrhage (very rare)

- Complications unique to the cervical approach\(^2\)\(^-\)\(^7\):
  - Accidental C0-C1 puncture (fluoroscopic guidance)
  - Spinal cord puncture
  - Spinal cord contrast injection
  - Vascular injury (Variant anatomy of vertebral artery or PICA)
  - Spinal cord hemorrhage (exceedingly rare)
C1-2 approach: Complications

- Review of the literature reveals case reports and small series describing complications of C1-2 puncture
  - All cases with complications were performed under fluoroscopic guidance
  - The majority of cases involved cervical myelography and reported as complications adverse events related to neck hyperextension
  - Thus, the number of reported complications related to “C1-2 puncture for cervical myelography” overestimates the risks associated with the C1-2 approach in general

- Robertson et al. performed a mail survey of neuroradiologists to determine modes of practice and major complications
  - 220 respondents reported 68 complications in an estimated total of 187,300 cervical myelograms
  - 2/3 of complications related to patient positioning/hyperextension
  - 1/3 related to the actual C1/2 puncture
## C1-2 approach: Complications

<table>
<thead>
<tr>
<th>Injury</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positioning</strong></td>
<td></td>
</tr>
<tr>
<td>N = 42 (63%)</td>
<td></td>
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<tr>
<td>42 hyperextension</td>
<td>1 death</td>
</tr>
<tr>
<td></td>
<td>7 quadraparesis</td>
</tr>
<tr>
<td></td>
<td>7 paraparesis</td>
</tr>
<tr>
<td></td>
<td>27 worsened neuro deficit</td>
</tr>
<tr>
<td><strong>Cervical puncture</strong></td>
<td></td>
</tr>
<tr>
<td>N = 25 (37%)</td>
<td></td>
</tr>
<tr>
<td>3 arterial injuries</td>
<td>1 death</td>
</tr>
<tr>
<td>2 vertebral arteries</td>
<td>2 full recovery</td>
</tr>
<tr>
<td>1 PICA</td>
<td></td>
</tr>
<tr>
<td>5 cord punctures</td>
<td>1 death</td>
</tr>
<tr>
<td></td>
<td>1 persistent neuro deficit</td>
</tr>
<tr>
<td></td>
<td>3 recovered</td>
</tr>
<tr>
<td>16 cord contrast injections</td>
<td>8 persistent neuro deficit</td>
</tr>
<tr>
<td></td>
<td>8 complete recovery</td>
</tr>
<tr>
<td>1 epidural hematoma</td>
<td>1 recovery after surgical intervention</td>
</tr>
</tbody>
</table>

*Modified from Robertson et al. Radiology 1990*
Katoh et al. reviewed 112 cases of lateral C1-2 puncture for cervical myelography using fluoroscopic guidance. In this study, 10 of 112 (9%) of the cases had technical complications:
- 3 cases of cord puncture and injection of contrast
- 3 cases of inadvertent puncture between the occiput and C1
- 1 case of epidural venous plexus puncture
- 1 case of epidural space contrast injection

Of these ten cases, only one patient had neurologic deficits: a case of cord injection with metrizamide resulting in permanent left sided hypoalgesia below the C2 level.

The authors conclude that the complications primarily resulted from two technical factors:
- Positioning of the neck
- Misdirection of the x-ray beam
C1-2 approach: Complications

- Neurologic deficits associated with intramedullary contrast injection generally occur immediately and typically improve after the procedure.

- The severity of symptoms appears to be related to volume injected and contrast type: all significant complications were reported after metrizamide injection\(^3,7,12\).

- Simon et al. reported a case of intramedullary contrast injection and reviewed reported cases of this complication\(^7\):
  - A total of 26 cases were found.
  - Pain during injection was reported in 6 cases (1 patient had no pain, 19 cases did not report symptoms).
  - Symptoms after the procedure included pain, hallucinations, meningisumus, quadriparesis, paraparesis, arm weakness.
  - Outcomes were reported in 23 of the cases:
    - 10 patients had persistent neurologic deficits.
    - In 11 cases there was complete resolution of symptoms.
    - 2 patients died.
C1-2 approach: Complications

- A small number of hemorrhagic complications are found as case reports in the literature
- Rogers (1983) reported the death of a patient from extensive cervical and intracranial subdural hemorrhage
  - In this case, an anomalous vertebral artery was found
  - The patient had received 5 cervical punctures without incident before his death after the 6th puncture
- Mapstone (1983) reported a case of extensive multicompartment hemorrhage after cervical puncture of a coagulopathic child with leukemia
- Abla (1986) described a case of delayed subarachnoid hemorrhage 36 hours after C1-2 myelogram
  - Emergent surgical decompression was performed
  - The patient had mild long term neurologic sequelae
- Aghi (2004) reported a case of subarachnoid hemorrhage, asceptic meningitis, and hydrocephalus after cervical puncture
  - Emergent surgical decompression and clot evacuation was performed
  - The patient recovered without neurologic sequelae
C1-2 approach: Relevant Anatomy

- Two vascular variants put patients at increased risk of arterial laceration producing hematoma, spasm, thrombosis or rarely, subarchnoid hemorrhage with the cervical approach:
  - Anomalous course of the vertebral artery
  - Low-lying PICA loop or low PICA origin

- Typically, the entire course of the PICA is confined to the intracranial compartment

- Siclari et al. report two cases of PICA origin at the C2 level\(^{14}\)

- Tokuda et al. found that 2 of 300 patients studied had PICA origin at C2\(^{15}\)
  - These PICAs did not traverse the posterior 1/3 of the canal, thus would not have been along the trajectory of a C1-2 puncture

Extradural origin of PICA, penetrating the dura between C1 and C2 (modified from Fine et al. J Neurosurgery 1999.)\(^{16}\)
Brinjikji and colleagues studied 346 PICAs in 211 patient cerebral angiograms in order to determine the frequency of PICA origin or descent below the C1 level\textsuperscript{17}

2 of 346 PICAs evaluated (0.6\%) extended below the C1 arch, thus at potential risk in the setting of C1-2 puncture

No PICA origins were found below C1

280/346 PICAs (80.9\%) were entirely located above the foramen magnum

64/346 PICAs (18.5\%) were located below the foramen magnum but above the inferior aspect of the posterior C1 arch
Katoh et al reviewed 164 vertebral artery catheter angiograms in order to determine the incidence of an anomalous course potentially dangerous in the setting of cervical puncture.

In 3/164 cases (1.9%) the vertebral artery passed over the posterior 1/3 of the canal: the target site for cervical puncture.

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage</th>
<th>Count</th>
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<tbody>
<tr>
<td>Anterior to the canal</td>
<td>70.6%</td>
<td>113</td>
</tr>
<tr>
<td>Anterior 1/3 of the canal</td>
<td>26%</td>
<td>45</td>
</tr>
<tr>
<td>Mid canal</td>
<td>1.9%</td>
<td>3</td>
</tr>
<tr>
<td>Posterior canal</td>
<td>1.9%</td>
<td>3</td>
</tr>
</tbody>
</table>
Relevant Anatomy: Vertebral artery

- A rare variation of the vertebral artery is partial duplication or fenestration.

- While nearly non-existent in American and European literature, Kowada et al. identified these anomalies in 1% (22/1685) of angiograms performed on Japanese patients.\(^{18}\)

- Rogers’ report of death from subdural hemorrhage, described earlier, was hypothesized to have resulted from puncture of this very rare variant.

Modified from Rogers, J Neurosurg 1983\(^4\)
C1-2 approach: expanded indications

- In addition to indications described previously, these patient populations would benefit from CT guided cervical puncture as a first line approach
  - Benefit from supine position: safety and/or comfort
    * Intubation
    * Respiratory difficulties
    * Recent abdominal or chest surgery
    * Neck or shoulder pain
  - Minimize position changes
    * Trauma, cervical collar, halo
    * If myelography is performed, the patient remains in the same position for scanning after contrast injection
  - Difficulty moving or maneuvering
    * Elderly
    * Obtunded
  - Lumbar stenosis with desired contrast destination in the cervical spine or intracranial compartment
    * Contrast enhanced CT cisternogram for CSF leak
C1-2 approach: possible expanded indications

- Would patients with high body mass index (who would require a 7 inch or longer spinal needle) benefit from a CT guided cervical approach?
  - Fluoro-guided lumbar puncture in patients with high BMI takes longer, is more difficult, and results in greater radiation exposure to patient and operator\(^{19}\)
  - If the cervical approach is used, it is likely that a shorter needle could reach the target
  - Direct visualization of the target would allow estimation of needle depth and fewer confirmatory CT checks would be necessary, thus potentially decreasing radiation dose

- Would cancer patients with significant lumbar stenosis benefit from cervical rather than lumbar puncture for instillation of intrathecal chemotherapy?
Summary

- C1-2 puncture is infrequently performed, and likely underutilized
  - Perceived to be more dangerous and difficult
  - Younger radiologists and trainees have not received sufficient practice to become comfortable and competent

- Despite decreased use of myelography, cervical puncture for CSF collection and contrast or chemotherapy injection remains relevant, and required in certain situations

- Careful review of the literature reveals only a small number of complications related to the cervical approach
  - All studies used fluoroscopic guidance
  - Nearly all complications related to injection of metrizamide into the cord
  - CT guidance further decreases the risks

- Increased utilization of this approach will benefit patients directly, with increased safety and comfort in some scenarios, and indirectly, as neuroradiology trainees develop competence and confidence to perform this important procedure