Case Report

Intradural calcifying pseudoneoplasm of the neuraxis presenting as a cauda equina syndrome

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Abstract

**Background:** Calcifying nonneoplastic pseudoneoplasms of the neuraxis (CAPNON) have been reported in 59 cases in literature, however, they rarely involve the spinal cord. Owing to the advances in immunohistochemical markers, their structure and origin are better understood now.

**Case Report:** We present the case of a 72-year-old female who had longstanding history of low back pain that exacerbated 20 days prior to the presentation to the emergency room with a frank cauda equina syndrome. The lumbar computed tomography scan showed a hyperdense lesion, suggestive of calcified tumor, whereas the magnetic resonance imaging revealed a hypointense lesion on the T1 and T2-weighted images, without contrast enhancement or edema on fluid-attenuated inversion recovery. She underwent an emergent L2-L4 laminectomy and L3-L4 discectomy with resection of L2 intradural tumor, following which she regained normal function.

**Conclusion:** A 72-year-old female presented with a cauda equina syndrome attributed to an L2 intradural CAPNON. Following gross total resection, the patient was neurologically intact.

**Key Words:** Calcifying nonneoplastic pseudoneoplasms (CAPNON), differential diagnosis, intradural, neoplasm, spine

INTRODUCTION

Calcified pseudoneoplasms of the neuraxis (CAPNON) are nonneoplastic lesions that rarely involve the central nervous system (CNS) and particularly the spine. Clinical features depend on the site of the lesion and may vary from asymptomatic to severely symptomatic; surgical resection is an effective treatment modality. [1,2]

Although the clinical presentation is often characterized by pain, with no neurological impairment, neurological deficits may occur if there is significant compression of the neural structures. Here, we describe a 72-year-old...
female who presented with an acute cauda equina syndrome attributed to CAPNON; following gross total excision, the patient was neurologically intact.

**CASE REPORT**

A 72-year-old female, with a longstanding history of low back pain, noted exacerbation of pain 20 days prior to admission with a cauda equina syndrome (2/5 proximal and 0/5 distal strength). A lumbar spine computed tomography (CT) scan showed a hyperdense intravertebral lesion of uncertain etiology (e.g., calcified tumors/ectopic calcifications inside vertebral canal vs. calcified embryological remnants). A lumbar magnetic resonance (MR) revealed with a lesion that was hypointense on T1 and T2-weighted images and showed no enhancement with contrast and no edema on fluid-attenuated inversion recovery studies [Figures 1 and 2]. She underwent an L2-L4 laminectomy and L3-L4 discectomy, as well as the resection of an L2 intradural tumor [Figure 3]. During surgery, the lesion was not adherent to the lumbosacral roots but displaced the nerve roots while contributing to cauda equina compression. Gross total resection of this extremely calcified lesion was accomplished [Figure 4].

Postoperatively, the patient was discharged on postoperative day 4 with residual proximal 4/5 and distal 2/5 residual motor deficits.

**DISCUSSION**

History and etiology of calcifying nonneoplastic pseudoneoplasms

Although common in the limbs, calcifying pseudoneoplasms (CAPNON) are rare lesions in the CNS (brain or spine).

To date, 59 cases have been described in the literature; 32 in the brain and 27

![Figure 1: Lumbar computed tomography scan: hyperdense lesion, suggestive of a calcified tumor](image1)

![Figure 3: Intraoperative image: intradural calcified lesion](image3)

![Figure 2: T1- and T2-weighted magnetic resonance imaging shows hypointensity in both series and no enhancement by contrast](image2)

![Figure 4: Histological section of calcifying nonneoplastic pseudoneoplasms stained for hematoxilin and eosin (a) and immunohistochemical expression for glial fibrillary acidic protein (GFAP), epithelial membrane antigen (EMA), and smooth muscle actin (b, c, and d, respectively). Optical microscopy, augmented ×200 (blue bar); (a) extensive laminating and concentric arranged calcified lesion with bone formation trabecules associated with fibrous tissue; (b) small and round cell proliferation with minimal atypia surrounding the calcified and fibrous lesion which expressed GFAP; (c) strong and diffuse expression for EMA in the same surrounding cells which denotes ependymal differentiation; (d) fibro-osseous lesion immunostained for smooth muscle actin that demonstrated fibroblastic differentiation](image4)
in the spine [Tables 1 and 2].[5,7,4] They are more frequent in the cervical segment (7), followed by thoracic (5) and lumbar (4) regions. For the spinal lesions, 14 were extradural involving a vertebral body, but only 2 were intradural.

Clinical presentation and magnetic resonance/computed tomography characteristics
All spinal cord lesions presented with back or cervical pain; only 4 had neurological deficits involving the upper and/or lower extremities.[4] CT studies showed that these lesions are a hyperdense lesion while MR studies demonstrated hypointense T1- and T2-weighted images with limited edema and contrast enhancement.[1] Differential diagnoses include meningioma, granulomatous lesions, astrocytoma with calcification, oligodendrogliomas, and hamartomas.[7]

Histopathology and immunology
The common histopathologic features of CAPNON include (1) typical chondromyxoid matrix in a nodular pattern; (2) palisading spindle-to-epithelioid cells; (3) variable amounts of fibrous stroma; (4) calcification, osseous metaplasia, and scattered psammoma bodies; and (5) foreign-body reaction with giant cells.[5] The presence of each component is highly variable, and some examples may not show all of the abovementioned elements.[7]

In general, it stains positive for epithelial membrane antigen (EMA) and vimentin and negative for S100 protein and glial fibrillary acidic protein (GFAP). Smith et al. found positive immunoreactivity to GFAP and S-100 protein in their report of an “unusual fibro-osseous lesion.”[8]

Surgical management and histopathology and immunological assessment
Gross total resection of this calcified intradural lesion adherent to the cauda equina and filum

Table 1: Calcifying nonneoplastic pseudoneoplasm

| Case | Author and Year | Age/Sex | Localisation | Treatment | Follow-up (months) | Recurrence |
|------|-----------------|---------|--------------|-----------|--------------------|------------|
| 1    | Duque, 2016     | 48 F    | Left atrium  | GT        | 18                 | No         |
| 2    | Kerr, 2011      | 56 M    | Right cerebellopontine angle | ST      | 6                  | No         |
| 3    | Rhodes and Davis, 1978 | 27 F | Right frontal lobe | ST      | 64                 | No         |
| 4    | Jun and Burdick, 1984 | 55 M | Corpus callosum | GT      | N                  | No         |
| 5    | Garen, 1989     | 44 M    | Trigeminal ganglion region | ST      | N                  | No         |
| 6    | Bertoni, 1990   | 31 M    | Left jugular foramen | ST      | 156                | Yes        |
| 7    | Bertoni, 1990   | 48 M    | Right cerebellar tonsil | GT      | 228                | No         |
| 8    | Bertoni, 1990   | 32 M    | Frontal lobe  | GT        | 360                | No         |
| 9    | Bertoni, 1990   | 58 M    | Jugular foramen | ST      | N                  | N          |
| 10   | Tsugu, 1999     | 22 F    | Right parietal lobe | GT      | 96                 | No         |
| 11   | Shrier, 1999    | 32 F    | Left temporal lobe | GT      | 12                 | No         |
| 12   | Qian, 1999      | 33 F    | Left temporal lobe | GT      | 31                 | No         |
| 13   | Qian, 1999      | 47 F    | Parasagittal frontal | GT      | 72                 | No         |
| 14   | Qian, 1999      | 49 M    | Clivus         | GT        | 90                 | No         |
| 15   | Tatke, 2001     | 6 M     | Left temporal medial region | ST      | 6                  | No         |
| 16   | Aiken, 2009     | 16 M    | Right temporal horn | GT      | N                  | No         |
| 17   | Aiken, 2009     | 35 M    | Right temporal lobe | GT      | N                  | N          |
| 18   | Aiken, 2009     | 49 F    | Left hippocampus | GT      | N                  | N          |
| 19   | Aiken, 2009     | 59 M    | Right parietal lobe | GT      | N                  | N          |
| 20   | Montibeller, 2009 | 67 F  | Right inferior colliculus | GT      | 18                 | N          |
| 21   | Mohapatra, 2010 | 48 M    | Right temporobasal region | GT      | N                  | No         |
| 22   | Hodges, 2011    | 36 M    | Left cerebellopontine angle | ST      | 7                  | No         |
| 23   | Stienen, 2011   | 46 M    | Right parietal lobe | ST      | 10                 | No         |
| 24   | Stienen, 2011   | 56 F    | Left frontoparietal lobe | ST      | 22                 | No         |
| 25   | Muccio, 2012    | 55F     | Cervicomedullary junction | GT      | 14                 | No         |
| 26   | Nonaka, 2012    | 56 M    | Right temporal lobe | GT      | N                  | N          |
| 27   | Nonaka, 2012    | 35 M    | Left occipital condyle | ST      | 6                  | No         |
| 28   | Grabowski, 2013 | 49 F    | Pineal region  | GT        | 21                 | No         |
| 29   | Fatih, 2014     | 59 F    | Cerebellomedullary cistern | GT      | N                  | N          |
| 30   | Wisniewski, 2015 | 29 M  | Foramen magnum  | GT        | 2                  | No         |
| 31   | Tan, 2016       | 45 M    | Superior medullary velum | GT      | 3                  | No         |
| 32   | Alshareef, 2016 | 59 F    | Cervicomedullary junction | ST      | 12                 | No         |

GT: Gross resection; ST: Subtotal resection; N: Not described
terminale (size 2.0 × 1.5 × 0.5 cm) was accomplished. Histopathologically, it was calcified (e.g., laminar radiated distribution), accompanied by fibro-osseous metaplastic tissue and a rhyme of small epithelioid cells through the neuropil. Immunohistochemistry demonstrated focal expression of GFAP, S-100 protein, and EMA (“dot” pattern).

With immunohistochemistry, this was a primary CNS lesion composed of glioneuronal cells with probable ependymal origin that differentiated to benign fibro-osseous calcifying tissue. Therefore, the possibility of a neoplastic nature cannot be excluded.

To date all reported cases have been treated surgically, either by complete or incomplete resection.[7] Notably, partially resected tumors showed no regrowth.[8]

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Table 2: Spinal calcifying nonneoplastic pseudoneoplams

| Case | Author and Year | Age/Sex | Localisation | Treatment | Follow-up (months) | Recurrence |
|------|----------------|---------|--------------|-----------|--------------------|------------|
| 1    | Brock, 2016    | 72 F    | L2id         | GT        | 6                  | No         |
| 2    | Duque, 2016    | 51 F    | L2ie         | GT        | 39                 | No         |
| 3    | Duque, 2016    | 46 F    | C3io         | GT        | 27                 | No         |
| 4    | Duque, 2016    | 73 M    | D2ie         | GT        | 12                 | No         |
| 5    | Bertoni, 1990  | 50 M    | FMe          | ST        | 42                 | No         |
| 6    | Bertoni, 1990  | 23 M    | Th10e        | ST        | N                  | No         |
| 7    | Bertoni, 1990  | 58 M    | C2e          | ST        | 112                | No         |
| 8    | Bertoni, 1990  | 12 M    | C6e          | ST        | 39                 | No         |
| 9    | Bertoni, 1990  | 32 M    | L4e          | ST        | 83                 | No         |
| 10   | Bertoni, 1990  | 33 F    | Th9e         | ST        | N                  | No         |
| 11   | Bertoni, 1990  | 68 F    | L4e          | ST        | 16                 | No         |
| 12   | Bertoni, 1990  | 20 F    | C2e          | ST        | N                  | No         |
| 13   | Bertoni, 1990  | 56 F    | L4e          | ST        | N                  | No         |
| 14   | Smith, 1994    | 48 M    | L2e          | GT        | N                  | No         |
| 15   | Shrier, 1999   | 59 M    | FMe          | GT        | 24                 | No         |
| 16   | Qian et al., 1999 | 59 M | C1e          | GT        | 46                 | No         |
| 17   | Chang, 2000    | 60 M    | C2io         | ST        | 24                 | Yes        |
| 18   | Mayr, 2000     | 58 M    | Th10e        | ST        | 48                 | No         |
| 19   | Mayr, 2000     | 63 M    | C3e          | ST        | 60                 | No         |
| 20   | Liccandro, 2003| 40 M    | Th8e         | GT        | 36                 | No         |
| 21   | Park, 2008     | 59 F    | C7e          | GT        | N                  | No         |
| 22   | Tong, 2010     | 67 F    | L4e          | Laminectomy | N          | No         |
| 23   | Ozdemir, 2011  | 53 M    | FMid         | GT        | N                  | No         |
| 24   | Muccio, 2012   | 57 M    | T10-11e      | GT        | 2                  | N         |
| 25   | Song, 2015     | 77 F    | T12e         | GT        | 5                  | No         |
| 26   | Song, 2015     | 67 F    | L2-3e        | GT        | N                  | N         |
| 27   | Song, 2015     | 78 F    | L1e          | GT        | N                  | N         |
| 28   | Singh, 2016    | 90 F    | C7-D1id      | ST        | N                  | N         |

GT: Gross resection; ST: Subtotal resection; N: Not described; FM: Foramen magnum; TH: Thoracic spinal segment; C: Cervical spinal segment; L: Lumbar spinal segment; E: Epidural; IE: Intradural extramedullary; ID: Intradural; IO: Intraosseous
female who presented with an acute cauda equina syndrome attributed to CAPNON; following gross total excision, the patient was neurologically intact.

**CASE REPORT**

A 72-year-old female, with a longstanding history of low back pain, noted exacerbation of pain 20 days prior to admission with a cauda equina syndrome (2/5 proximal and 0/5 distal strength). A lumbar spine computed tomography (CT) scan showed a hyperdense intravertebral lesion of uncertain etiology (e.g., calcified tumors/ectopic calcifications inside vertebral canal vs. calcified embryological remnants). A lumbar magnetic resonance (MR) revealed a lesion that was hypointense on T1 and T2-weighted images and showed no enhancement with contrast and no edema on fluid-attenuated inversion recovery studies [Figures 1 and 2]. She underwent an L2-L4 laminectomy and L3-L4 discectomy, as well as the resection of an L2 intradural tumor [Figure 3]. During surgery, the lesion was not adherent to the lumbosacral roots but displaced the nerve roots while contributing to cauda equina compression. Gross total resection of this extremely calcified lesion was accomplished [Figure 4].

Postoperatively, the patient was discharged on postoperative day 4 with residual proximal 4/5 and distal 2/5 residual motor deficits.

**DISCUSSION**

**History and etiology of calcifying nonneoplastic pseudoneoplasms**

Although common in the limbs, calcifying pseudoneoplasms (CAPNON) are rare lesions in the CNS (brain or spine).[^2][^3]. They be found at any age but are more common in patients over 50 years old, and are more typically noted in males.[^2][^5] In some publications, they are associated with neurofibromatosis type 2.[^3] To date, 59 cases have been described in the literature; 32 in the brain and 27

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[^2]: Reference 1
[^3]: Reference 2
[^4]: Reference 3
[^5]: Reference 4

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**Figure 1:** Lumbar computed tomography scan: hyperdense lesion, suggestive of a calcified tumor

**Figure 2:** T1- and T2-weighted magnetic resonance imaging shows hypointensity in both series and no enhancement by contrast

**Figure 3:** Intraoperative image: intradural calcified lesion

**Figure 4:** Histological section of calcifying nonneoplastic pseudoneoplasms stained for hematoxilin and eosin (a) and immunohistochemical expression for glial fibrillary acidic protein (GFAP), epithelial membrane antigen (EMA), and smooth muscle actin (b, c, and d, respectively). Optical microscopy, augmented ×200 (blue bar); (a) extensive laminating and concentric arranged calcified lesion with bone formation trabecules associated with fibrous tissue; (b) small and round cell proliferation with minimal atypia surrounding the calcified and fibrous lesion which expressed GFAP; (c) strong and diffuse expression for EMA in the same surrounding cells which denotes ependymal differentiation; (d) fibro-osseous lesion immunostained for smooth muscle actin that demonstrated fibroblastic differentiation
in the spine [Tables 1 and 2]. They are more frequent in the cervical segment (7), followed by thoracic (5) and lumbar (4) regions. For the spinal lesions, 14 were extradural involving a vertebral body, but only 2 were intradural.

**Clinical presentation and magnetic resonance/computed tomography characteristics**

All spinal cord lesions presented with back or cervical pain; only 4 had neurological deficits involving the upper and/or lower extremities. CT studies showed that these lesions are a hyperdense lesion while MR studies demonstrated hypointense T1- and T2-weighted images with limited edema and contrast enhancement. Differential diagnoses include meningioma, granulomatous lesions, astrocytoma with calcification, oligodendrogliomas, and hamartomas.

**Histopathology and immunology**

The common histopathologic features of CAPNON include (1) typical chondromyxoid matrix in a nodular pattern; (2) palisading spindle-to-epithelioid cells; (3) variable amounts of fibrous stroma; (4) calcification, osseous metaplasia, and scattered psammoma bodies; and (5) foreign-body reaction with giant cells. The presence of each component is highly variable, and some examples may not show all of the abovementioned elements.

In general, it stains positive for epithelial membrane antigen (EMA) and vimentin and negative for S100 protein and glial fibrillary acidic protein (GFAP). Smith et al. found positive immunoreactivity to GFAP and S-100 protein in their report of an “unusual fibro-osseous lesion.”

**Surgical management and histopathology and immunological assessment**

Gross total resection of this calcified intradural lesion adherent to the cauda equina and filum

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**Table 1: Calcifying nonneoplastic pseudoneoplasm**

| Case | Author and Year | Age/Sex | Localisation | Treatment | Follow-up (months) | Recurrence |
|------|-----------------|---------|--------------|-----------|-------------------|------------|
| 1    | Duque, 2016     | 48 F    | Left atrium  | GT        | 18                | No         |
| 2    | Kerr, 2011      | 56 M    | Right cerebellopontine angle | ST | 6 | No |
| 3    | Rhodes and Davis, 1978 | 27 F | Right frontal lobe | ST | 84 | No |
| 4    | Jun and Burdick, 1984 | 55 M | Corpus callosum | GT | N | No |
| 5    | Garen, 1989     | 44 M    | Trigeminal ganglion region | GT | N | No |
| 6    | Bertoni, 1990   | 31 M    | Left jugular foramen | ST | 156 | Yes |
| 7    | Bertoni, 1990   | 48 M    | Right cerebellar tonsil | GT | 228 | No |
| 8    | Bertoni, 1990   | 32 M    | Frontal lobe | GT | 360 | No |
| 9    | Bertoni, 1990   | 58 M    | Jugular foramen | ST | N | N |
| 10   | Tsugu, 1999     | 22 F    | Right parietal lobe | GT | 96 | No |
| 11   | Shrier, 1999    | 32 F    | Left temporal lobe | GT | 12 | No |
| 12   | Qian, 1999      | 33 F    | Left temporal lobe | GT | 31 | No |
| 13   | Qian, 1999      | 47 F    | Parasagittal frontal | GT | 72 | No |
| 14   | Qian, 1999      | 49 M    | Clivus | GT | 90 | No |
| 15   | Tatke, 2001     | 6 M     | Left temporal medial region | ST | 6 | No |
| 16   | Aiken, 2009     | 16 M    | Right temporal horn | GT | N | No |
| 17   | Aiken, 2009     | 35 M    | Right temporal lobe | GT | N | N |
| 18   | Aiken, 2009     | 49 F    | Left hippocampus | GT | N | N |
| 19   | Aiken, 2009     | 59 M    | Right parietal lobe | GT | N | N |
| 20   | Montibeller, 2009 | 67 F  | Right inferior colliculus | GT | 18 | N |
| 21   | Mohapatra, 2010 | 48 M    | Right temporobasal region | GT | N | No |
| 22   | Hodges, 2011    | 36 M    | Left cerebellopontine angle | ST | 7 | No |
| 23   | Stienen, 2011   | 46 M    | Right parietal lobe | ST | 10 | No |
| 24   | Stienen, 2011   | 56 F    | Left frontoparietal lobe | ST | 22 | No |
| 25   | Muccio, 2012    | 55 F    | Cervicomedullary junction | GT | 14 | No |
| 26   | Nonaka, 2012    | 56 M    | Right temporal lobe | GT | N | N |
| 27   | Nonaka, 2012    | 35 M    | Left occipital condyle | ST | 6 | No |
| 28   | Grabowski, 2013 | 49 F    | Pineal region | GT | 21 | No |
| 29   | Fatih, 2014     | 59 F    | Cerebellomedullary cistern | GT | N | N |
| 30   | Wisniewski, 2015 | 29 M  | Foramen magnum | GT | 2 | No |
| 31   | Tan, 2016       | 45 M    | Superior medullary velum | GT | 3 | No |
| 32   | Alshareef, 2016 | 59 F    | Cervicomedullary junction | ST | 12 | No |

GT: Gross resection; ST: Subtotal resection; N: Not described
terminale (size 2.0 × 1.5 × 0.5 cm) was accomplished. Histopathologically, it was calcified (e.g., laminar radiated distribution), accompanied by fibro-osseous metaplastic tissue and a rhyme of small epithelioid cells through the neuropil. Immunohistochemistry demonstrated focal expression of GFAP, S-100 protein, and EMA (“dot” pattern).

With immunohistochemistry, this was a primary CNS lesion composed of glioneuronal cells with probable ependymal origin that differentiated to benign fibro-osseous calcifying tissue. Therefore, the possibility of a neoplastic nature cannot be excluded.

To date all reported cases have been treated surgically, either by complete or incomplete resection.\[^{[7]}\] Notably, partially resected tumors showed no regrowth.\[^{[4]}\]

**Financial support and sponsorship**
Nil.

**Conflicts of interest**
There are no conflicts of interest.

**REFERENCES**

1. Aiken AH, Akgun H, Tihan T, Barbaro N, Glastonbury C. Calcifying pseudoneoplasms of the neuraxis: CT, MR imaging, and histologic features. AJNR Am J Neuroradiol 2009;30:1256-60.
2. Chang H, Park JB, Kim KW. Intraosseous calcifying pseudotumor of the axis: A case report. Spine 2005;25:1036-9.
3. Donev K, Scheithauer B. Pseudoneoplasms of the nervous system. Arch Pathol Lab Med 2010;134:404-16.
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**Table 2: Spinal calcifying nonneoplastic pseudoneoplasms**

| Case | Author and Year | Age/Sex | Localisation | Treatment | Follow-up (months) | Recurrence |
|------|-----------------|---------|--------------|-----------|--------------------|------------|
| 1    | Brock, 2016     | 72 F    | L2id         | GT        | 6                  | No         |
| 2    | Duque, 2016     | 51 F    | L2ie         | GT        | 39                 | No         |
| 3    | Duque, 2016     | 46 F    | C3io         | GT        | 27                 | No         |
| 4    | Duque, 2016     | 73 M    | D2ie         | GT        | 12                 | No         |
| 5    | Bertoni, 1990   | 50 M    | FMe          | ST        | 42                 | No         |
| 6    | Bertoni, 1990   | 23 M    | Th10e        | ST        | N                  | No         |
| 7    | Bertoni, 1990   | 58 M    | C2e          | ST        | 112                | No         |
| 8    | Bertoni, 1990   | 12 M    | C6e          | ST        | 39                 | No         |
| 9    | Bertoni, 1990   | 32 M    | L4e          | ST        | 83                 | No         |
| 10   | Bertoni, 1990   | 33 F    | Th9e         | ST        | N                  | No         |
| 11   | Bertoni, 1990   | 68 F    | L4e          | ST        | 16                 | No         |
| 12   | Bertoni, 1990   | 20 F    | C2e          | ST        | N                  | No         |
| 13   | Bertoni, 1990   | 56 F    | L4e          | ST        | N                  | No         |
| 14   | Smith, 1994     | 48 M    | L2e          | GT        | N                  | No         |
| 15   | Shrier, 1999    | 59 M    | FMe          | GT        | 24                 | No         |
| 16   | Qian et al., 1999 | 59 M  | C1e          | GT        | 46                 | No         |
| 17   | Chang, 2000     | 60 M    | C2io         | ST        | 24                 | Yes        |
| 18   | Mayr, 2000      | 58 M    | Th10e        | ST        | 48                 | No         |
| 19   | Mayr, 2000      | 63 M    | C3e          | ST        | 60                 | No         |
| 20   | Liccardo, 2003  | 40 M    | Th8e         | GT        | 36                 | No         |
| 21   | Park, 2008      | 59 F    | C7e          | GT        | N                  | No         |
| 22   | Tong, 2010      | 67 F    | L4e          | Laminectomy | N  | No         |
| 23   | Ozdemir, 2011   | 53 M    | FMid         | GT        | N                  | No         |
| 24   | Muccio, 2012    | 57 M    | T10-11e      | GT        | 2                  | N           |
| 25   | Song, 2015      | 77 F    | T12e         | GT        | 5                  | No         |
| 26   | Song, 2015      | 67 F    | L2-3e        | GT        | N                  | N           |
| 27   | Song, 2015      | 78 F    | L1e          | GT        | N                  | N           |
| 28   | Singh, 2016     | 90 F    | C7-D1id      | ST        | N                  | N           |

GT: Gross resection; ST: Subtotal resection; N: Not described; FM: Foramen magnum; TH: Thoracic spinal segment; C: Cervical spinal segment; L: Lumbar spinal segment; E: Epidural; IE: Intradural extramedullary; ID: Intradural; IO: Intraosseous