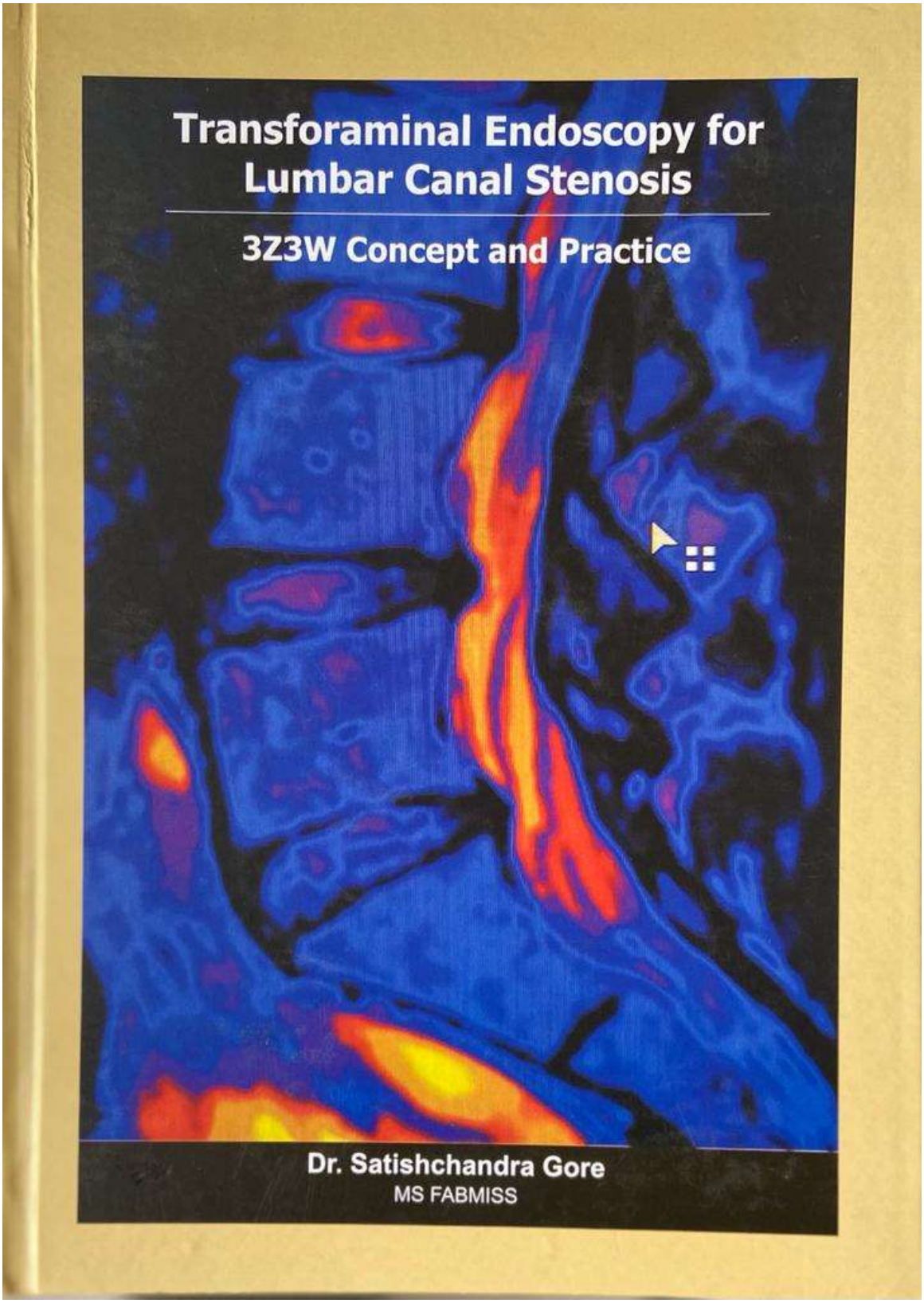
Transforaminal Endoscopy for Lumbar Canal Stenosis
3Z3W Concept and Practice
Dr. Satishchandra Gore
MS FABMISS

Transforaminal Endoscopy for Lumbar Canal Stenosis:

3 Zone 3 Walls

Concepts and Practice

GORE system by

Dr. Satishchandra Gore:

MS FABMISS

Mission Spine Foundation PUNE MS.

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I dedicate this book to

My wife Suneeti

And my daughters Smruti and Sneha

For their tolerance, encouragement, support and understanding of my work and odd routines.

My colleagues from mission spine who have supported and accepted my work.

My patients who may have been benefitted by this work.

Numerous critics, supporters in this paradigm change to spine surgery.

Satishchandra gore

13 April 2021.

Gudi Padwa

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Satishchandra Gore, 13 April 2021.

Transforaminal endoscopy for lumbar canal stenosis

3Z 3W concepts and practice of Gore System

Table of contents

Why this book, for advanced users?

Surgery by interlaminar route is more legacy than pure science wrt lumbar canal stenosis. Author is perplexed. Convenience is taken over science with apparent non-academic support. The pure endoscopy domain is being hijacked by "full endoscopy" and "minimally invasive" spine surgery. Instead of taking up complexity of spine anatomy and variations in causative factors as challenge, most are back to interlaminar midline surgery that has failed in innovating itself. Surgeon factor is very important. Usual talk is about steep learning curve going on for ages, instead if adequate time and energy is devoted to its pursuit, by this time we could have mastered TFE for stenosis.

In case of disc herniation pain generator as a concept changed our surgery towards root cause, TFE under local. This philosophy of transforaminal endoscopy with its focus on safety and targeting root cause is getting blurred. In stenosis adequate attention to changed canal walls at middle discal zone and its borders with upper and lower zone wrt 3 causes namely disc, facet and ligamentum flavum is needed. The transforaminal endoscopy under local anaesthesia, I am sure has now matured into a complete solution for degenerating lumbar spine.

In case of stenosis author feels changes in canal walls in proximity of neurovascular tissue and pathophysiology needs our attention. Instead we are still on incrementally removing more bone by newer tools and then taking up stabilisation as a final end solution. In a progressive inevitable change of stenosis; that may be symptomatic at an advanced age with comorbidities, we need better solution than open surgery.

This book is an attempt to rededicate our efforts to root cause analysis for stenosis and targeting causes simply by TFE and exploiting its true potential for our suffering patients.

- Dr. Satishchandra Gore.

1. Reorientation: and switch to stenosis

REORIENTATION: Transforaminal stitch less lumbar spine surgery done under local anaesthesia for disc was introduced in India by me on 19 November 1999 in PUNE. After working on it for 20 long years, I am introducing extension for lumbar canal stenosis now.

Lumbar canal narrowing can be treated by TFE [transforaminal endoscopy] in awake and aware patients. Pain generators guide our targeting in disc surgery. In case of stenosis changes occurring in close proximity of the nerve root are important targets. Crystal clear analysis of imaging for these causes is important.

The lumbar spine functional segment is formed by two vertebrae and interposed disc anteriorly and two vertebral arches forming facet joint behind with interlaminar ligamentum flavum. ONLY this interposed soft tissue changes with age; anterior or posteriorly in the lumbar canal walls giving symptoms. We land in middle discal zone that is housing thecal sac. In relation to our landing supradiscal is upper zone that has exiting root and infra discal or lower zone that houses the traversing root along root canal. Central canal stenosis is caused by changes posterolaterally along medial wall of facets where hypertrophied flaval tissue acts on JAWS OF facetal pincer compressing thecal sac bilaterally, may be starting on one side first.

We are aware changes occur in all 3 walls of the canal that is anterior, lateral and posterior due to 3 causes disc and margins anteriorly, facet and margins posterolaterally and ligamentum flavum posteriorly. The soft tissue in foramen adds to lateral causes in form of g knot. To access

all symptom generators entry in middle zone is easy, effective and scientific.

I have had 20 years of experience in transforaminal access for disc herniations with migrations and all variations. We can easily access the fragments in canal ventral to dural sac, by going over disc margins in upper zone and lower zone. The zone concept takes away the confusion about jargon [like lateral canal, foraminal stenosis, lateral recess stenosis, central canal stenosis and root canal entry zone, exit zone or similar jargon] that was constructed with posterior mid line access. Our method also does away with "hidden zone of Macnab" as we land in hidden zone as standard access. TFE for stenosis is being done for last 5 years by me.

Collapsed degenerated disc can add to problems in stenosis and needs a precise solution. I had introduced "intra discal spacer" B twin first time in India in January 2004 that is being relaunched as vajra. This can be used under local anaesthesia and transforaminal.

In lumbar canal I need to target stenotic roof or posterior wall changes, through foramen. There is a distinct need to raise tip of working instruments that seems difficult. Separation in space of landing area or anchor for scope and working tip end of instruments is needed and now possible due to my TEKU technology.

Lessons learnt: Central canal is from edge of facet to edge of other side facet. In open surgery we work inside these facet edge margins and when we try to transgress the margins for adequate decompression by cutting bone/ facet we may destabilise the joint. In open surgery we cannot easily go to upper lateral canal [in upper zone or upper foramen in axilla] that inability leads to failed surgery. Due to landing at 90 degree in middle zone, we may not be able to go on outside of the facet

or under its ventral face unless we do part or total facet removal. Recent change of going from opposite side over the top may help.

In lower zone lateral recess a mandatory medial facet removal in every patient may not be relevant to ventral or anterior wall cause.

However in TFE we land in upper lateral canal and work on roof of foramen, we can go above SAP and inside middle zone facet medial surface; additionally ventral to facet and it is easy to tackle all walls of lateral recess under local anaesthesia.

Ligamentum flavum location close to nerve roots decides our access. Our aim in surgery of stenosis is not total removal of posterior wall and ligamentum flavum but ONLY the one in proximity of the nerve roots. It is important to ascertain location of symptom causing changes pre operatively by appropriate imaging and a due consideration to variables in all 3 zones.

Image 1 blue U orange M and green L zone roof. Image 2 roof of all 3 zones with traversing nerve. Blue line is facet ridge, red dot entry part of root canal.

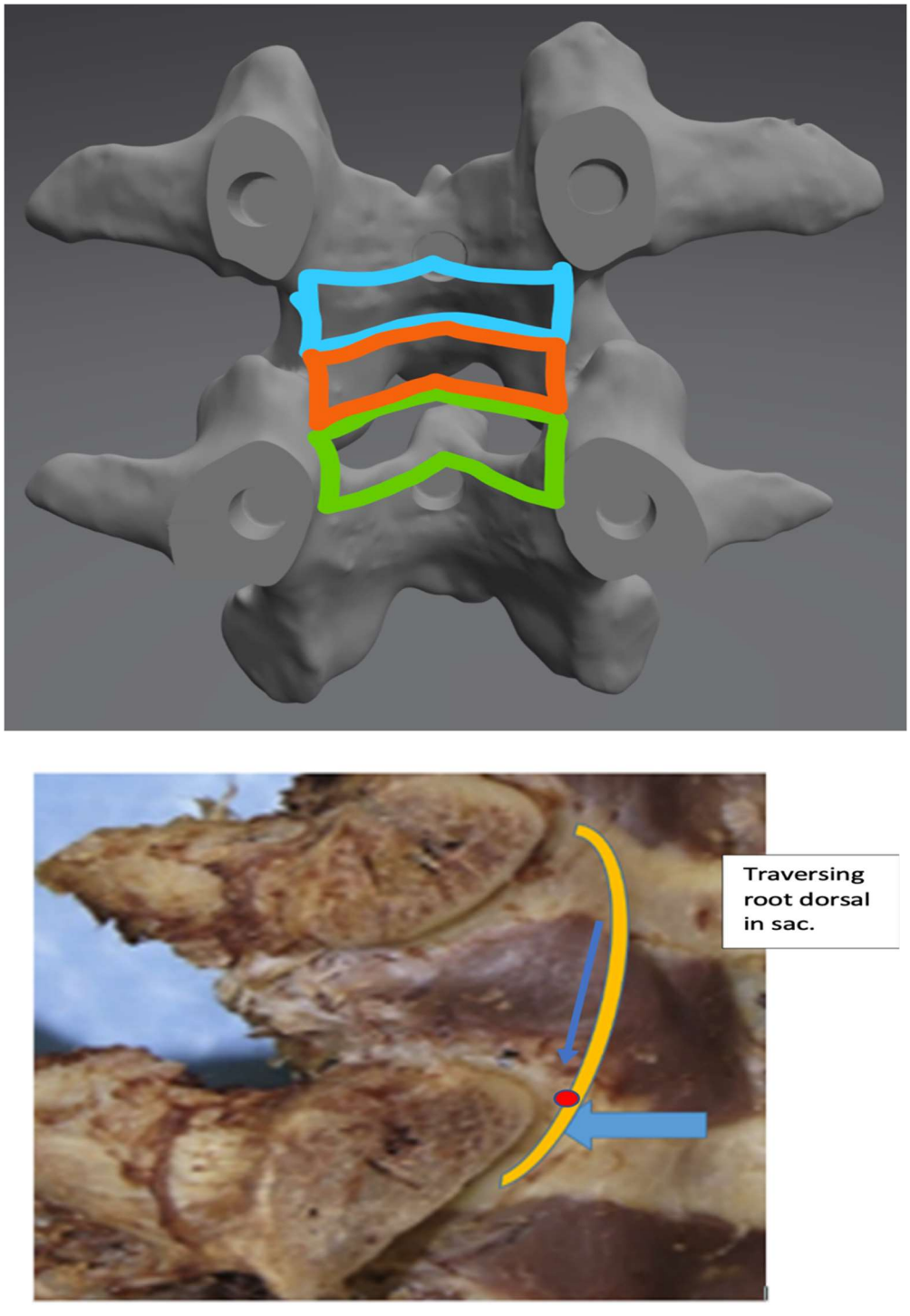
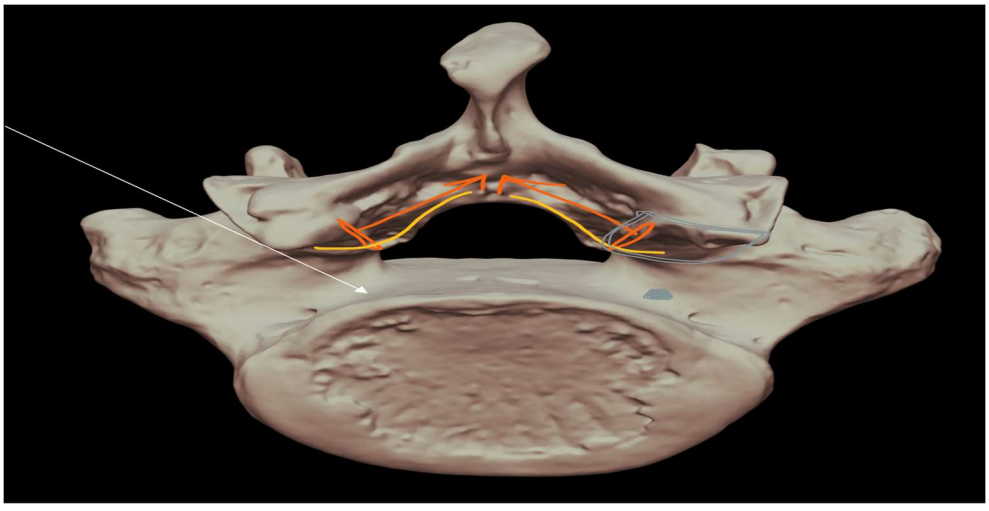


Image 3 Anatomy of posterior wall wrt TF landing in middle zone. White arrow is our path and black dot on right is landing. Yellow is ligamentum flavum and orange is central canal.



Targeting sub centimetre symptom generator by transforaminal endoscopy can yield lot of benefit in stenotic neurogenic claudication. This is significant for comorbid patients. In multilevel bilateral affection the surgery can be staged as it is under local anaesthesia.

We would like to highlight anatomy of our surgical targets by looking at coronal sections in a 3d model and build them up ventral to dorsal TO SUPPORT Transforaminal endoscopy as better and alternative solution for tackling stenosis. This image build up will highlight "hidden zone" that is normally not reachable and not seen in open midline posterior surgery. Our transforaminal surgery is lateral plane direct decompression of lumbar canal stenosis in all 3 zones under local anaesthesia unlike open midline posterior indirect [away from affected roots] decompression under general anaesthesia in 2 zones and one wall.

In upper zone we can see exiting root, and operculum of Forrestier that closes the foramen as lid. The root can be compressed at roof. We see lateral compression in middle zone [central] canal where roots are pinched in lateral arms of the pincer and this is NOT posterior midline

compression. In lower zone we will see relation or proximity or non-proximity of facet joint margins with traversing root at entry to root canal or ahead in canal.

In our 2D coronal images the traversing root looks like it is crossing edge of facet from medial to lateral, but this in 3D is root travels from roof of canal to ventral floor at entry to root canal part 1. Part of intrathecal traversing root from axilla above to this entry below is called interradicular part.

These images are used pre operatively to study our understanding of 3D anatomy. Since our working area during surgery is about 100-200 sq. mm we need to be very precise. Detailed study and this coronal build up will help all surgeons to pick up my technique and concepts faster.

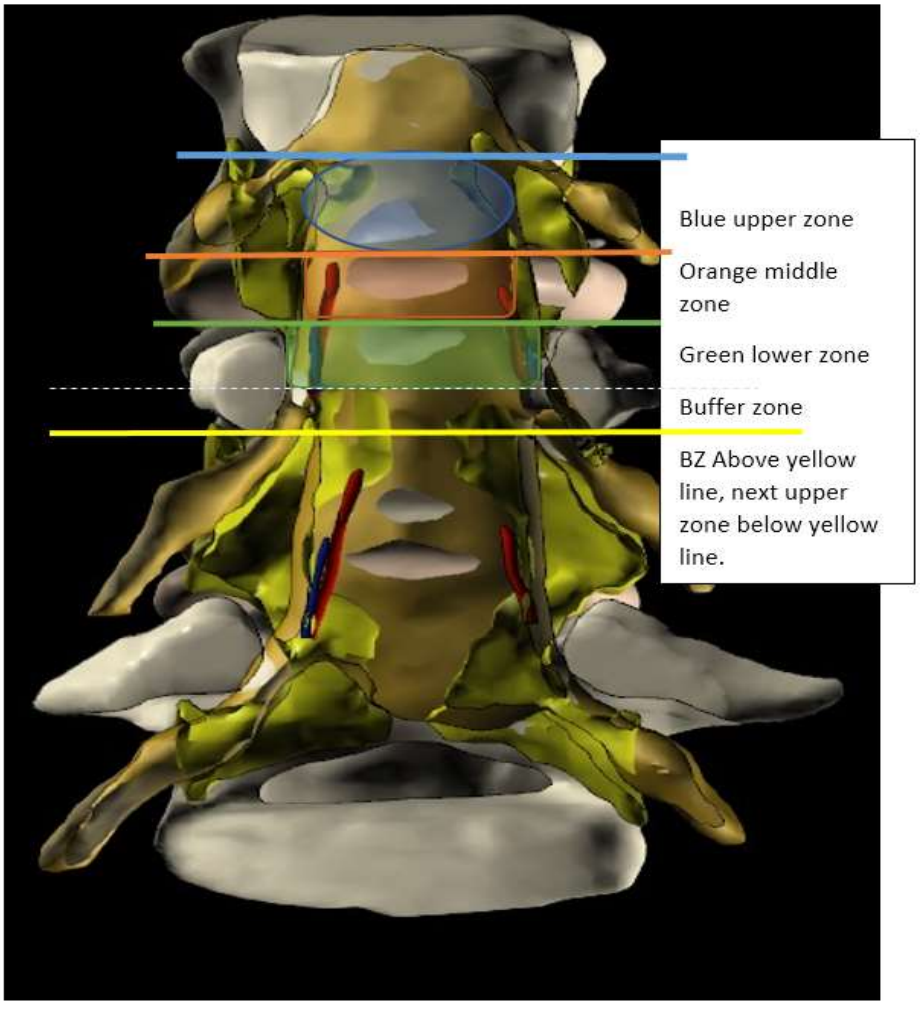


Image 4: 3 zones of the spinal segment, involving canal accessible from both sides.

Following images may be used to identify and mark these targets as pre op practice, to improve learning curve.

Blue upper zone, orange middle and green lower zone up to dotted line. Orange is central canal. Traditionally we are unable to reach to blue zone corners and green zone borders without cutting bone. Dotted line up to yellow line is buffer zone. In open surgery we enter at or close to green line. In endoscopy we enter orange zone.

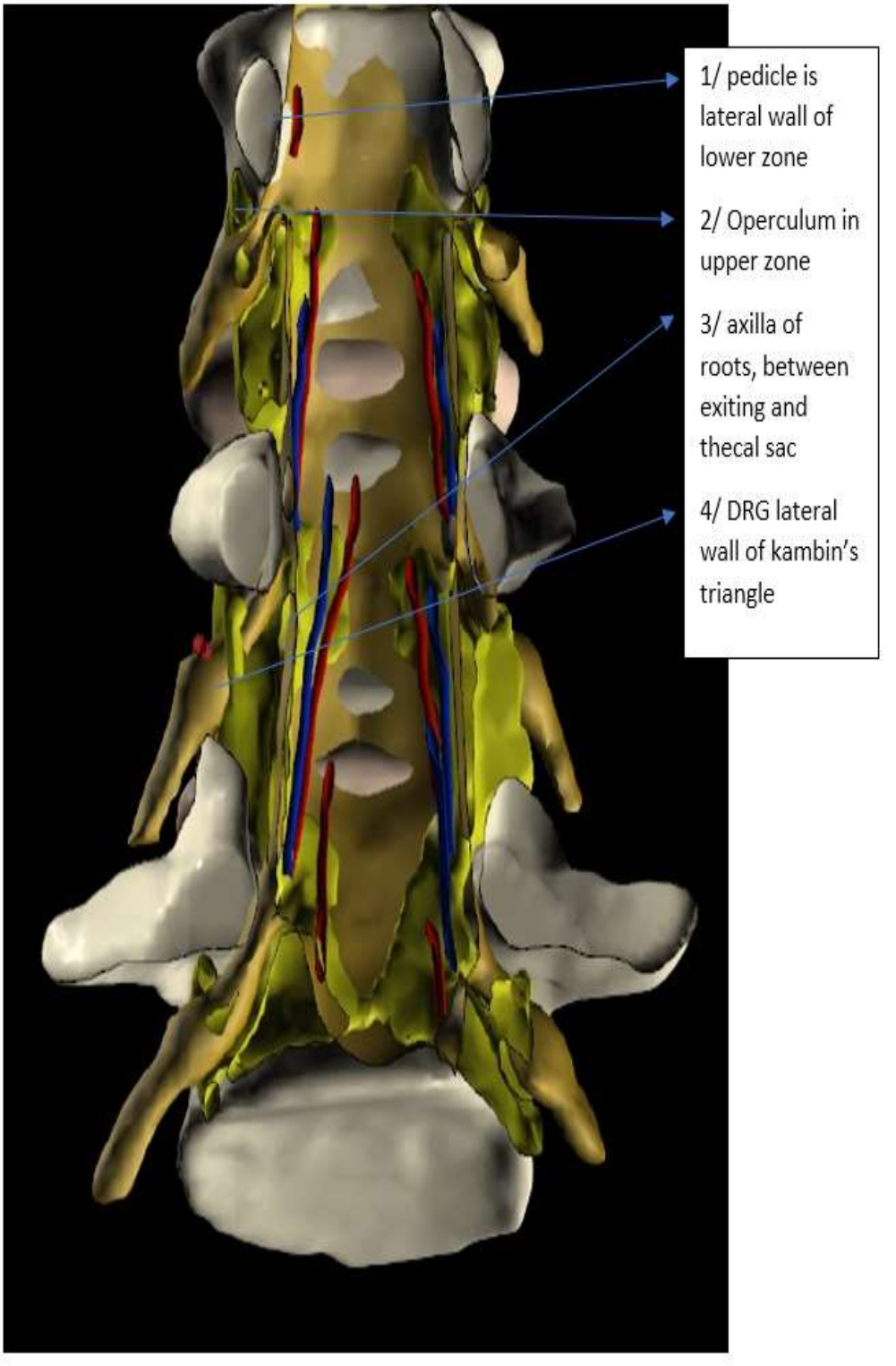


Image 5 Coronal perspective on foraminal and lateral recess anatomy.

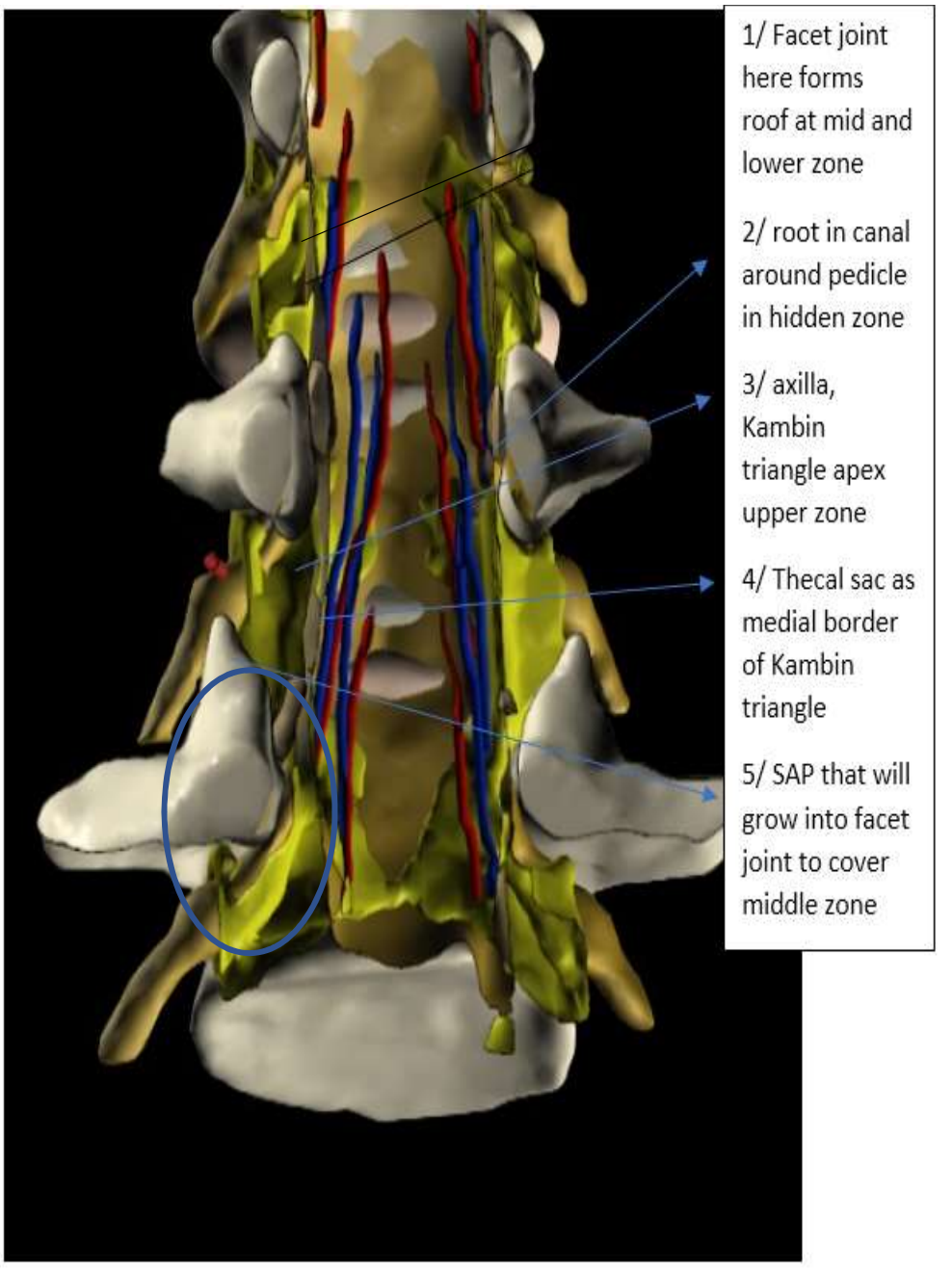


Image 6: Anatomy of the lumbar canal built up ventral to dorsal.

We will see it built up in following sequence of images from ventral to dorsal that will highlight soft tissue along sides of lateral wall of dural sac and bone coming in. Pars coming in. BLUE circle is the root canal.

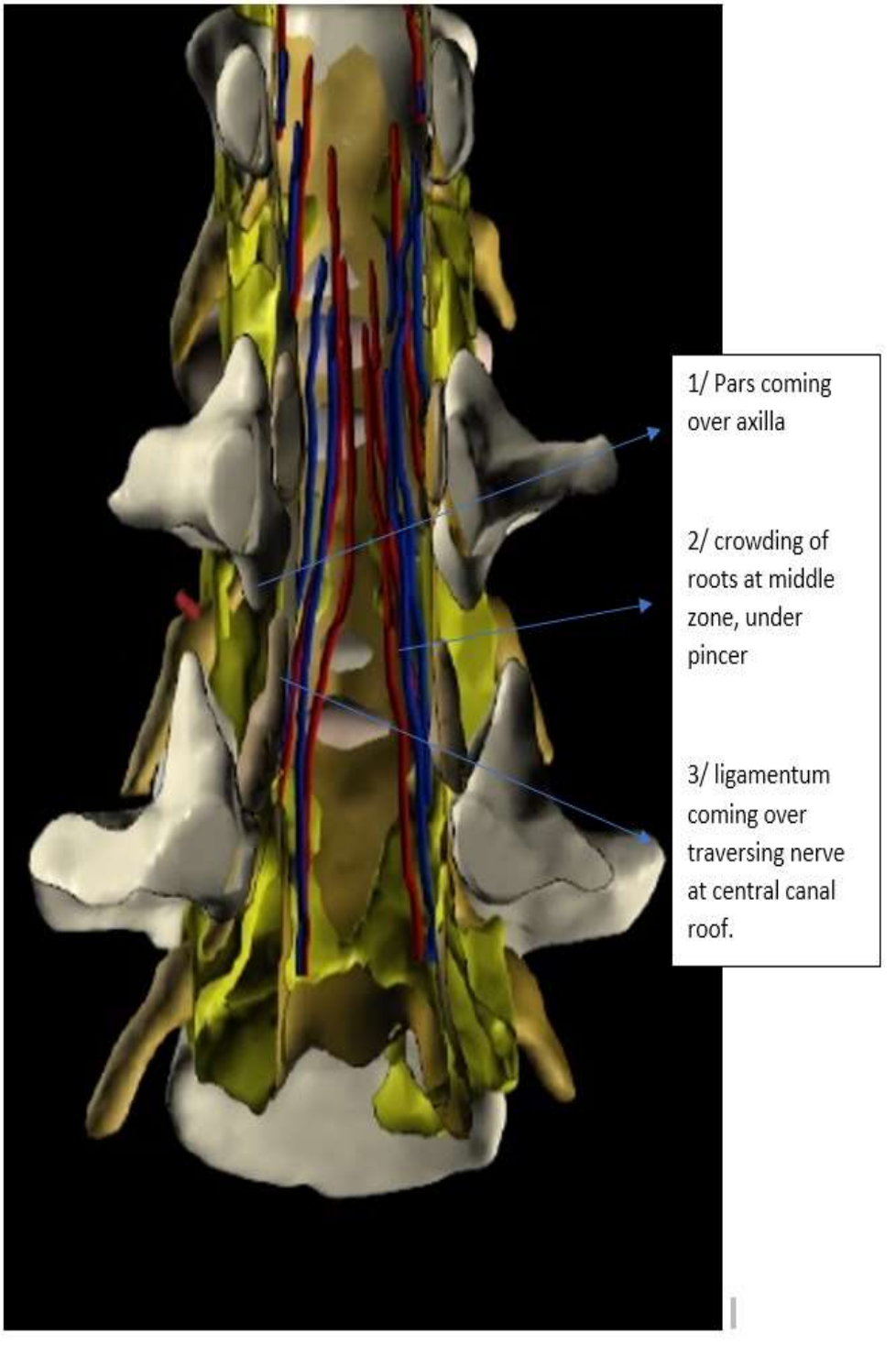


Image 7: Pars covering upper zone.

This is an important area as most causes of failed open surgery are here.

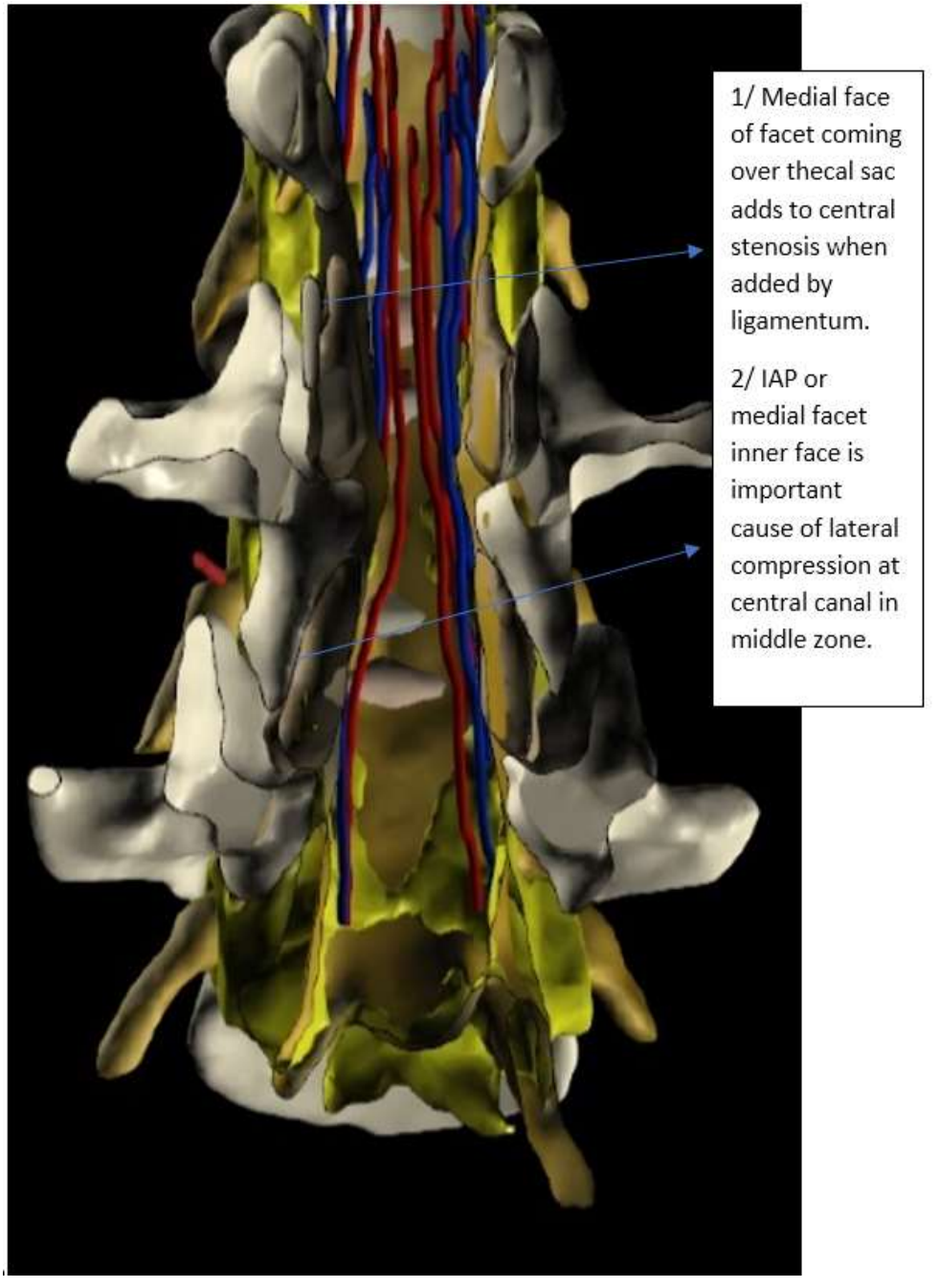


Image 8: Medial facet face covering central canal as pincer jaws.

From these images it is obvious that there are no central midline structures occupying thecal sac and post midline causes compressing it from behind. Roots float in CSF in thecal sac.

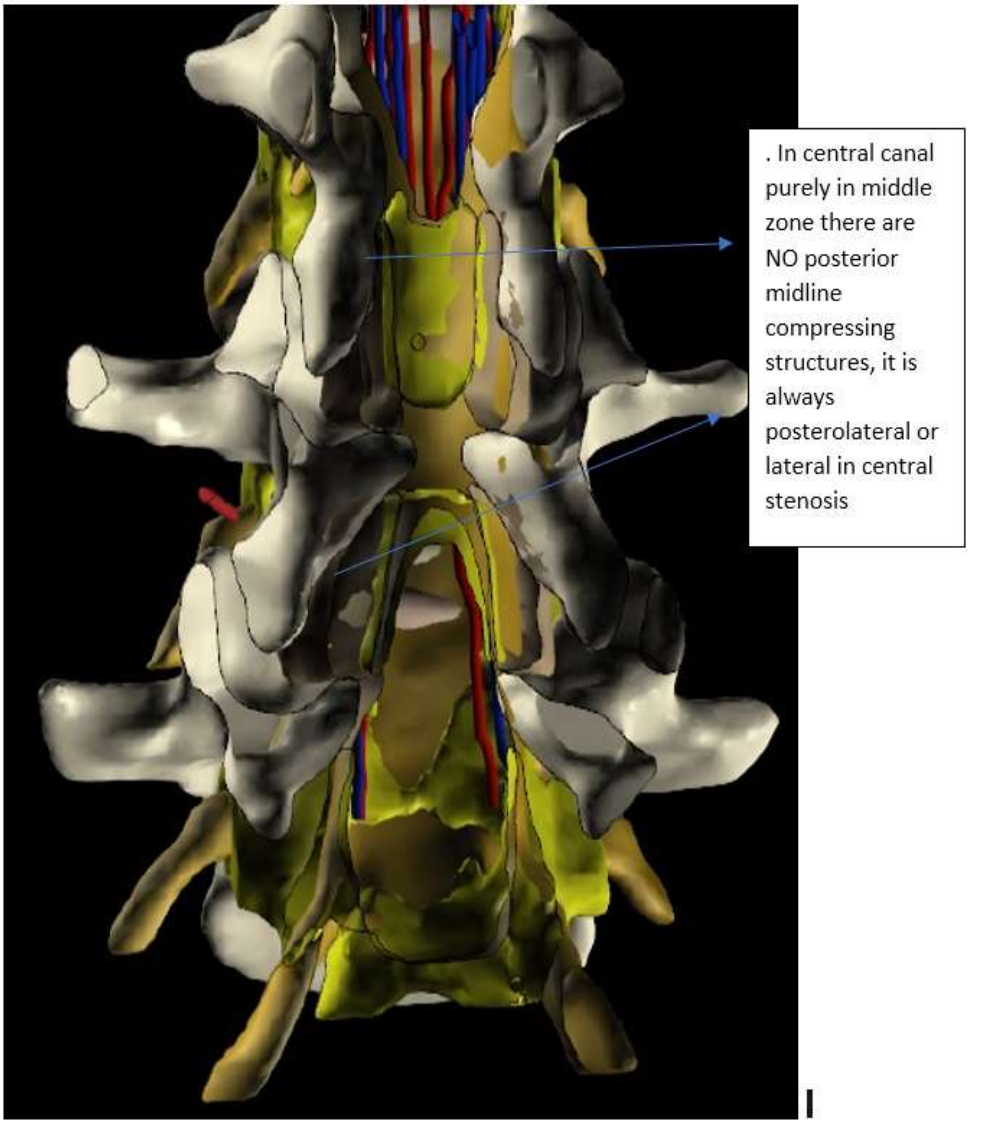


Image 9: Origin of compression in middle zone central canal.

Central canal is from edge of facet one to other side. Crowding of cauda roots is in no way related to any dorsal structures "compressing" dural sac [except in congenital narrow canal, short pedicles]. Central canal stenosis is really posterolateral.

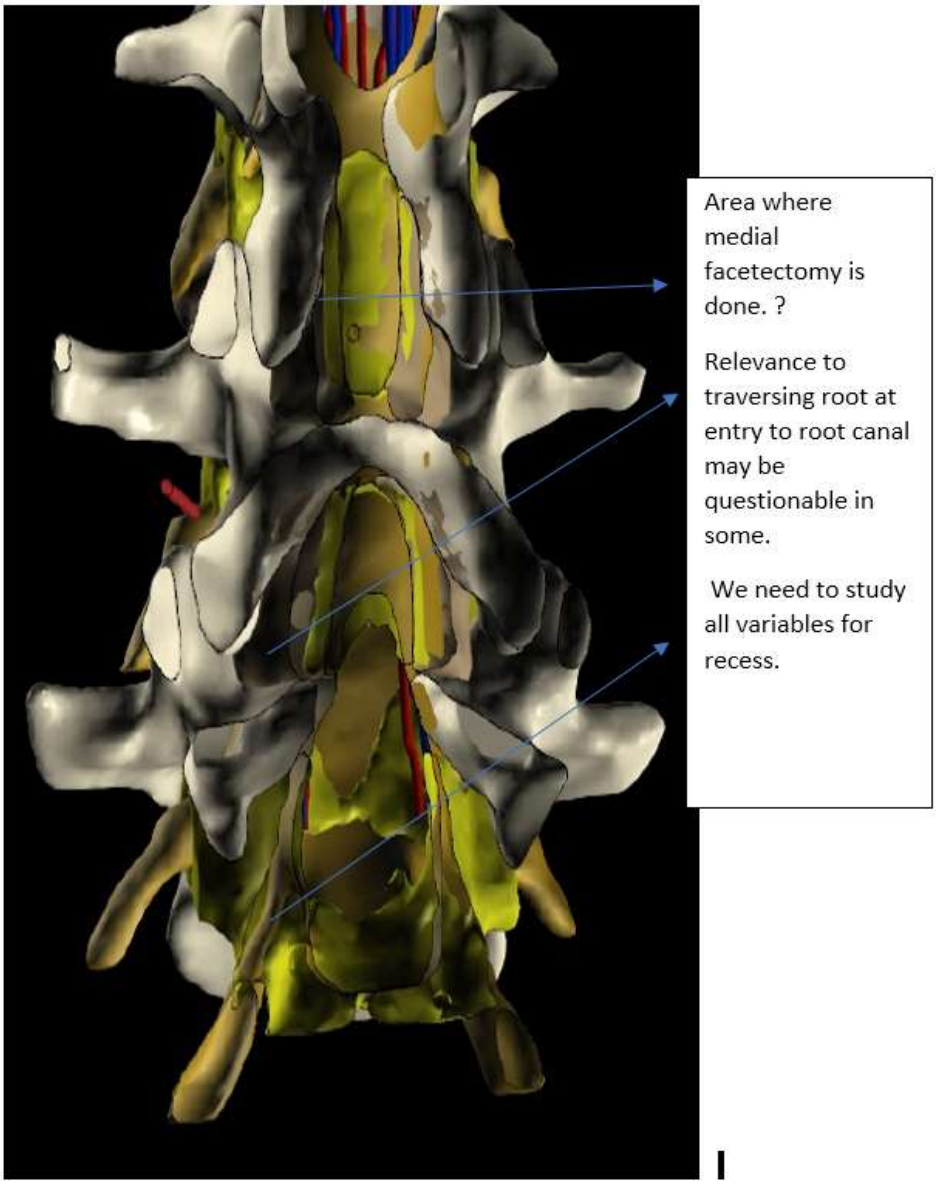


Image 10: Lateral recess has multiple variables that need attention.

Lateral recess has variables as to origin of root leaving thecal sac, laminar angle, location of axilla and DRG, bony dimensions of the recess, facet inclination. A detailed pre operative assessment is essential for better surgical plan and outcomes of interventions. This is hardly done routinely in traditional surgery.

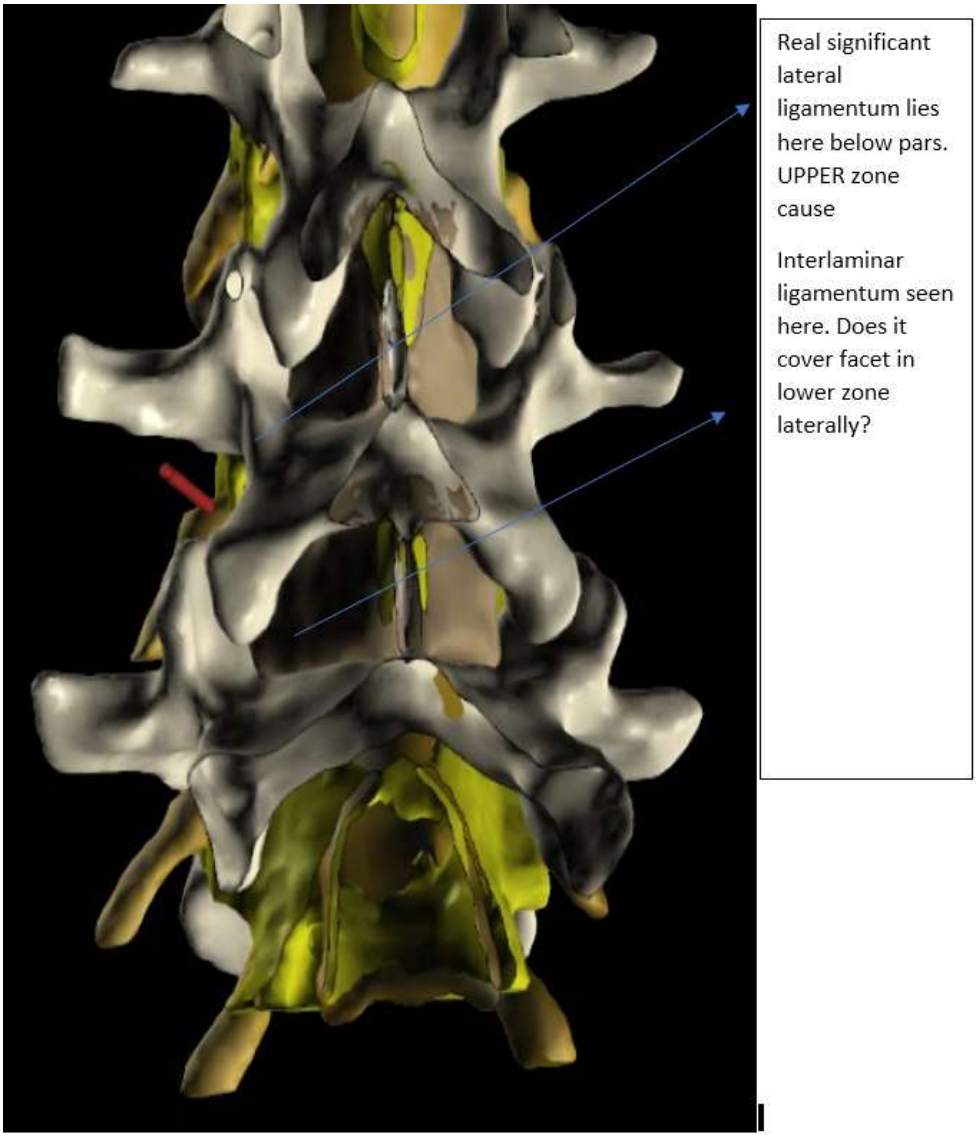
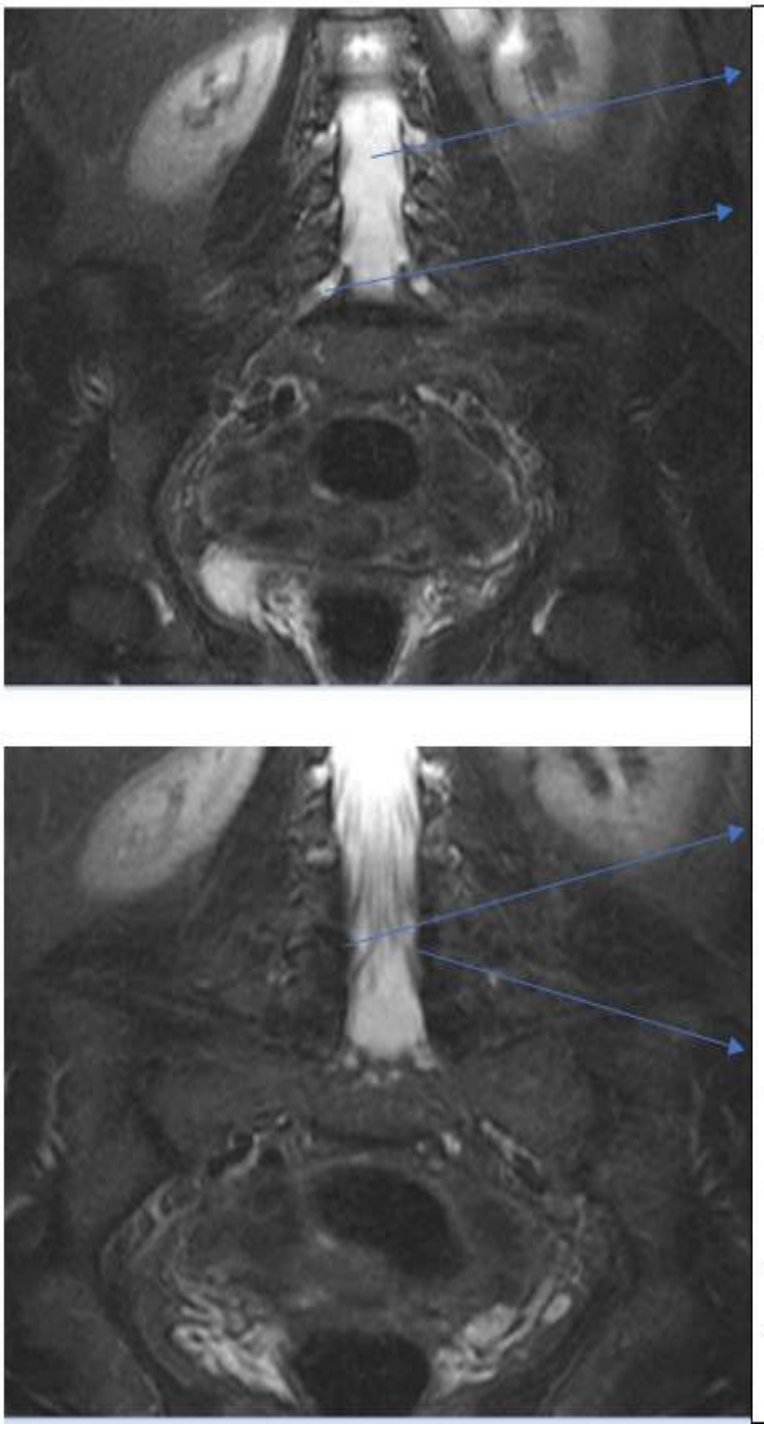


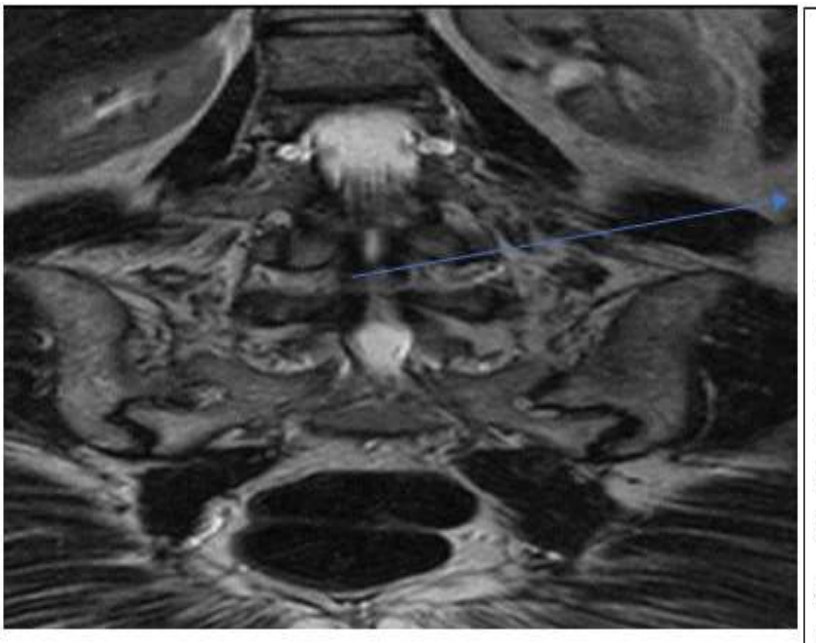
Image 11: Role of laminar arches and removal during open surgery.

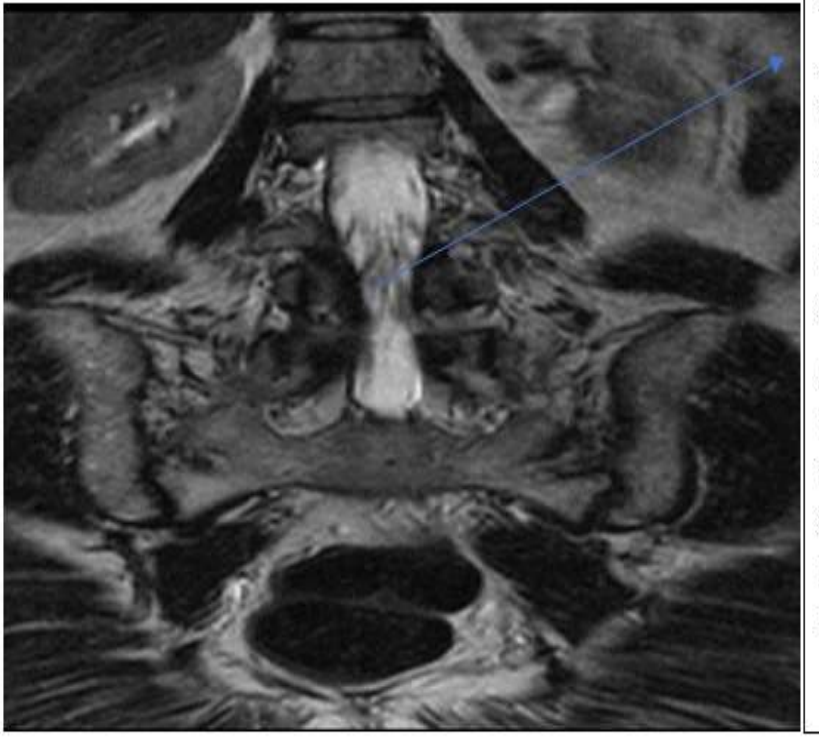
We must realize cutting lower bony ring as part of open surgery access is not relevant to decompression of affected roots. Removal of tissue along access is just to improve visual comfort. Upper zone is farthest from our posterior midline access. Ligamentum flavum is attached under upper lamina but on edge of lower lamina. Its enbloc removal is not needed. It is NOT relevant to symptom generation or its relief.

Simultaneous coronal build up in MRI may be easy to understand.

Images 12-17 coronal cuts showing MRI anatomy of the lumbar canal.







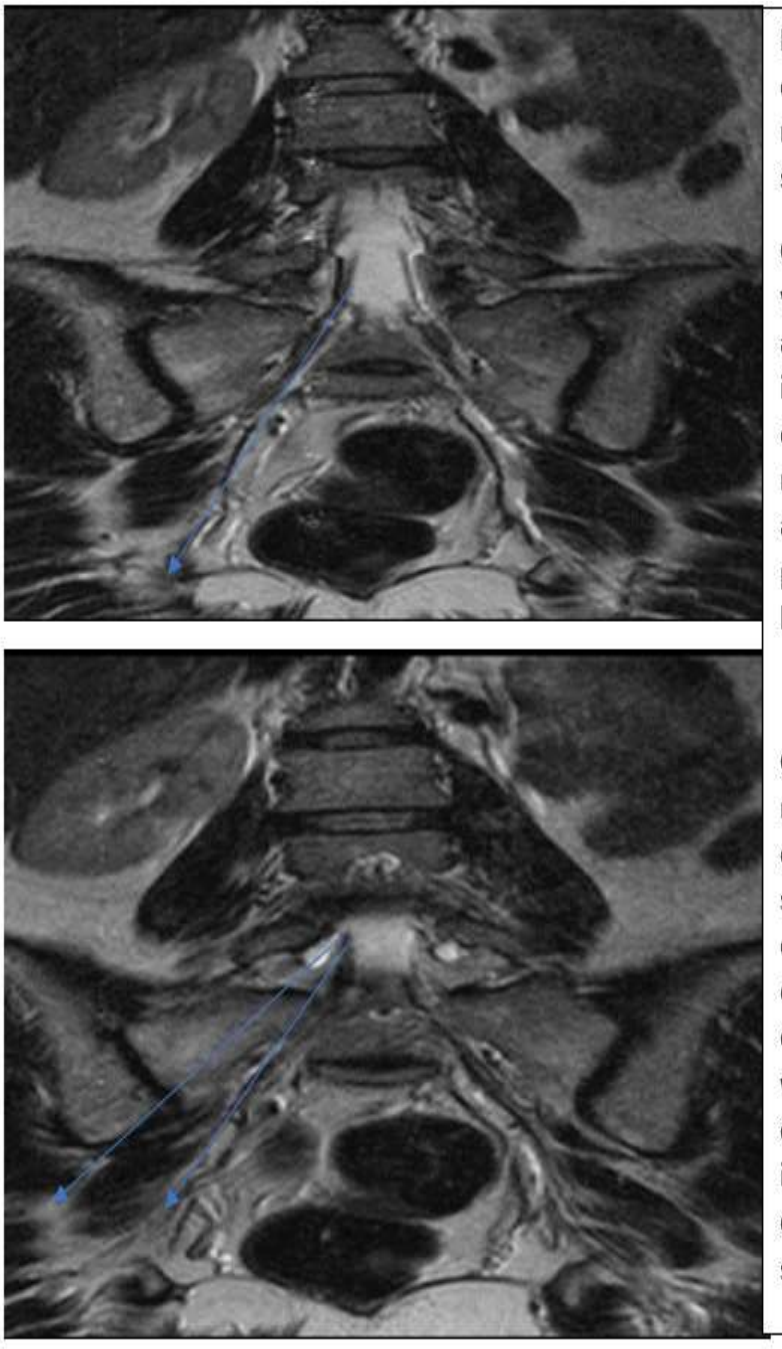
Medial wall of facet causes a lateral compression in central canal stenosis.

Seen here as it is building up.

This lateral encroachmen t of tissue in central canal may be unilateral to start with.

Open surgery has an access to both sides at same time but it is MORBID.

Image 14, 15: Bilateral transforaminal decompression can be an answer to this central canal cause.



Images 16, 17: Extrathecal course of roots in cauda equina. It is almost straight line , except it is immobile in root canal. Coronal images are to bring out the morbidity of our open access. This is totally avoidable by transforaminal access.

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3D images above are used under CC license from blue link anatomy university of Michigan.

3D scan of the fifth lumbar vertebrae Captured with Einscan Pro

Captured and edited by: Madelyn Murphy. Copyright 2019 BK Alsup & GM Fox

Web link: to the images and the cc and material

https://sketchfab.com/3d-models/lumbar-vertebrae-l5-labeled-0ebd171e42784153bd06f452cd79dd10

The image is not modified but only suitable annotations have been added.

The 3d model below of the posterior wall is cc Justin Cramer ©

This is a model of the L3-4 posterior elements with holes. This will snap into the separately available L3-4 anterior elements with dowels. The separately downloadable thecal sac snaps into these posterior elements as well, allowing you to print each part in a different colour.

Web link to cc material and images is at

https://sketchfab.com/3d-models/l3-4-posterior-with-holes-7f5dbeedcb904f3c9a9ec43a15f2a14c

Image is not modified but used only with added annotations with changed perspective for our surgery.

New way of treating stenosis: For access to disc, since I am already in lateral canal of upper and middle zone, I can easily work on foraminal walls to relieve the stenosis in foramen. I can work on soft tissue in upper foramen, in middle zone ventral face of the facet right up to facet edge and lower notch by burring inferior foraminal notch. In middle zone beyond foramen it leads to medial facet face and in lower zone onwards to part 1 and 2 of lateral recess. Following targets can be easily reached and acted on

TABLE 1: Targets in lumbar stenosis in 3 zones and walls

UT0 there is no disc or facet in upper zone. 0 is to highlight that.

UT1 hypertrophied soft tissue in sub pars and axilla area upper zone. This is most important in failed open surgery,

UT2 pars defect with hypertrophied fibrocartilage, repairing the defect.

MT3 medial facet face related changes in central canal stenosis.

MT4 disc related changes, osteophytes, migrations, old healed.

MT5 foraminal soft tissue g knot.

LT6 lower zone ventral to traversing nerve in part 1 lateral recess.

LT7 lower zone dorsal to nerve in part 2 lateral recess.

LT8 synovial cysts from facet, common in lower zone

U M L indicate zones.

T targets 3, 4, 6, 7, 8 are true channelplasty targets.

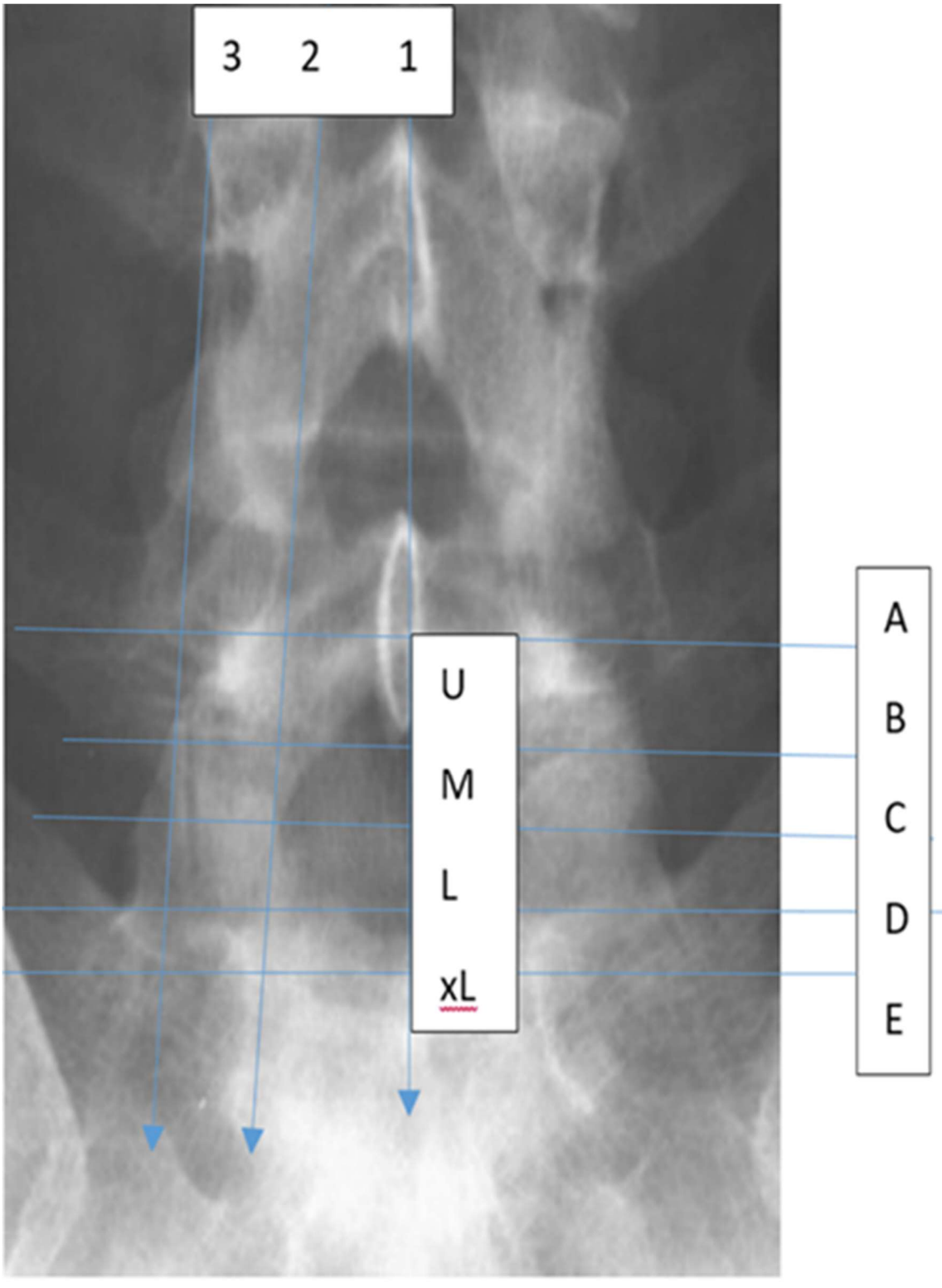
After landing in foramen, closer to medial pedicle line we cross it or facet edge thus entering channel for channelplasty.

Steps in stenosis surgery: 1-16 basic:

1. After passing through the fascia and muscles, the needle lands at Kambin's triangle under superior articular process in middle zone lateral wall
2. After checking AP and LAT images needle is directed to inside disc or towards upper or lower endplate as per identified target. Pre operatively knowing the likely target is essential.
3. In stenosis it is easy as we fix target locations wrt roots not pedicle.
4. They are fixed spots along entry of root canal in lower zone part 1 lateral recess and beyond part 3, exit in upper zone that follows. We change our angle accordingly.
5. If we use OUTSIDE IN philosophy, we land on outer face of ventral facet. [this is mainly for middle zone central canal]
6. This angle will also change if we are using a teku fulcrum technology with natural or artificial extraforaminal fulcrum that helps to access roof.
7. Upper zone we land close to upper end plate and use the tip of Sap as a guide further. We can access middle zone above SAP tip or after ventral SAP cutting and going to edge and then medial face of the facet.
8. Middle zone we must land and clarify edge of facet, with a pre op estimate about facet inclination [coronal or sagittal] we would be able to plan adequate under cutting of ventral facet.
9. Once on edge we may use hook, curette or hand held burr to work on facet edge to access the medial face ligamentum further. TARGET may be under surface of the facet edge or its inner wall in case of central canal i.e. middle zone stenosis.

10. It is easier to track ligamentum medial to Sap or facet by starting above tip of SAP. Starting from tip of sap and then working caudal along medial facet face works safer.
11. When working on lateral or ventral bony face of the facet we start from lower pedicle up, as it is safer and easier to see and feel. But when working on ligamentum flavum on medial face, looking at vascular anatomy of its deeper layer or presence of the peridural membrane it is advisable to start from SAP tip.
12. For lower zone we land in lower foraminal notch. Oozing is very common. Use of irrigation pressure and good plasma cautery is essential to clear the soft tissue from the lower bony notch.
13. We land in [ventral] plane under traversing or entering root fixed area in part 1. Awake patient feedback adds to safety.
14. We can use better trajectory or fulcrum or flexible tip of instrument to reach plane dorsal to root in part 2 of lateral recess.
15. In principle surgery steps are similar wrt handling instruments but mental visualization involved is about roof. Here is need of superfine imaging to equip your mind.
16. It is important to study anatomy of posterior wall of canal from front. This is very important learning.

For better mental visualization on AP c arm image we draw vertical lines
1 midline and
2 medial pedicle line
3 lateral pedicle line.
Area between medial [facet edge may be little more medial] and lateral pedicle lines 2-3 is foramen.
We land almost always at mid or medial pedicle line of L45 or L5S1 in middle zone.
Additionally, we draw following horizontal lines in AP image to delineate the zones
A. Line across Inferior border of pedicle,
B. Upper vertebral endplate line, [lower endplate of vertebra above or IEL. IEL is inferior endplate line, area above IEL is upper zone. NOTE tip of SAP is in this line seen in sagittal image dividing the foramen.
C. lower endplate at disc line, [upper endplate of lower vertebra]. For access to lower zone we land closer to lower endplate at disc level.
D. across mid across pedicle horizontal line that is lowest border of lower zone marking our surgical travel and
E. across next inferior border of lower [caudal] pedicle. Canal between D and e is buffer zone and is non-symptomatic in stenosis.
Importance of understanding anatomy in 3D see video links ".”
Access to AREA BETWEEN C AND D and all its walls WILL BE HOTLY CONTESTED BY OPEN SURGEONS AS DIFFICULT. This is lower zone and has parts in sagittal plane from above down. Soft tissue lateral recess, bony lateral recess and E is buffer zone.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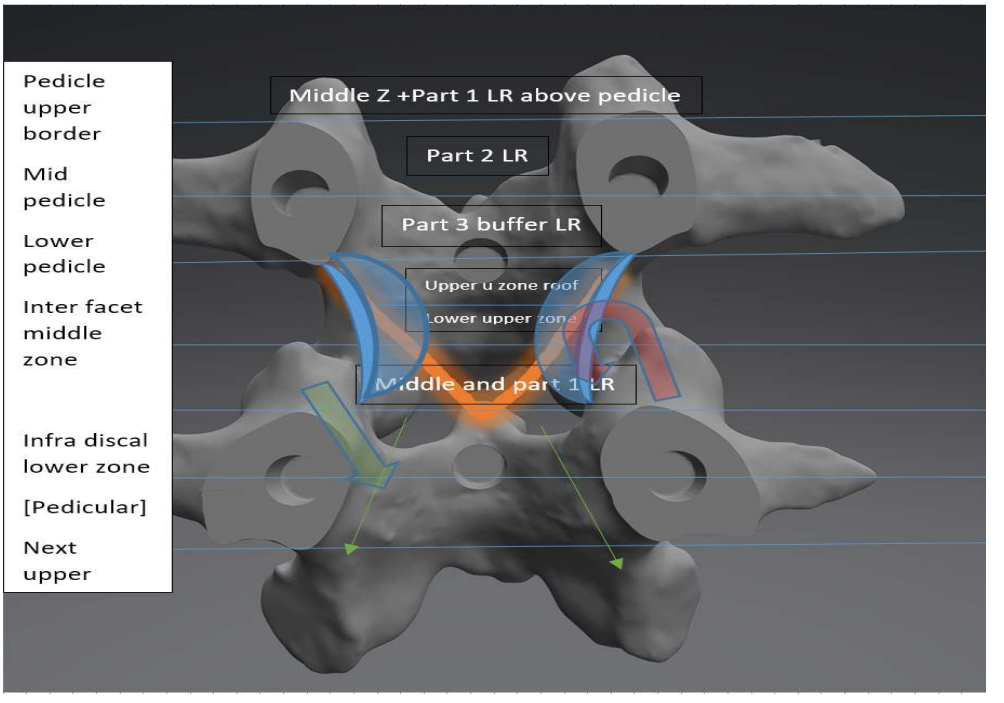
MASTER IMAGE: Roof and stenosis targets with strategy.



This image highlights central canal lined bilaterally by medial facet faces [thin blue arc areas] and facet edges [dark blue arcs] forming jaws of pincer. Ligament extends to lower laminar edges. The orange v highlights lay of the ligamentum flavum in roof of the central canal and its lateral part, lateral to facet edges. Pale green arrows are on facet edges. Big green arrow is access to lateral recess. WE land in middle and part 1 LR level.

Our strategy 1 is shown by arrows red middle to upper and then middle ahead. This involves cutting tip of SAP [shown on right of image]. We add facet undercutting to this.

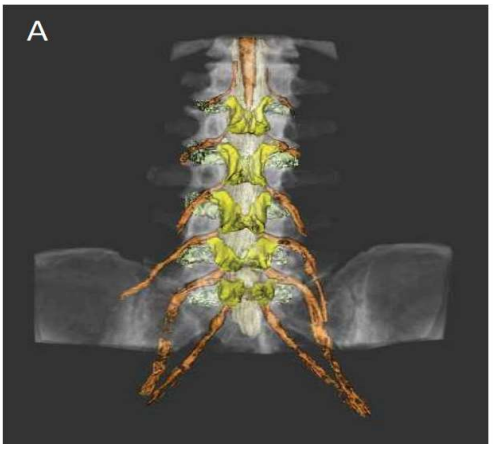
Strategy 2 by green big arrow as middle and lower zone ahead for floor at part 1 or roof at part 2. This may involve medial oblique pediculectomy [Shown on left of image].

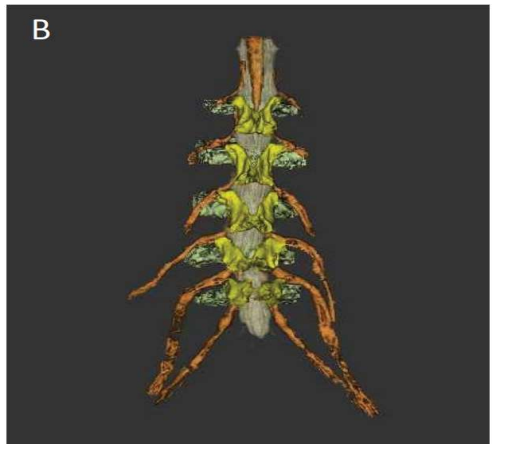
2 SPECIAL: ligamentum flavum in stenosis: LF by its lay decides our access areas.

LIGAMENTUM flavum is the only structure traversing all 3 zones obliquely roof [UZ], subarticular [MZ] and medial face of facet [m] and is sparse over facet lower pole [LZ].and determines our roof access points. It causes symptoms only in its sub articular, foraminal and extra foraminal part. We can remove symptomatic part without bone removal unlike open surgery.

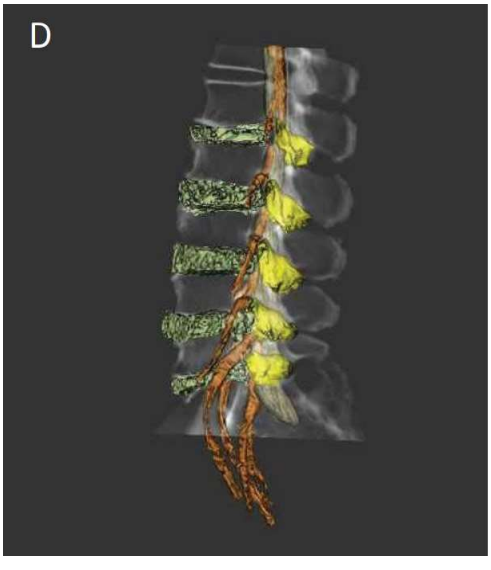
Change is about its lateral subarticular part and sub pars roof of upper foramen part. Subarticular part of ligament is important in central middle zone canal stenosis and subpars in upper zone foraminal stenosis. This lower and upper zone area is the key area that compresses the axilla depending on its location at L45 or L5S1, and we need to appreciate that this is the area that is at narrowest point in canal in sagittal or cross sectional plane better seen in oblique coronal and sagittal images. The lamina slopes down and up from here. Compression in "central" canal is not dorsal posterior midline structure related but posterolateral ligamentum flavum cover of facet edge and inner facet wall acting like jaws of a pincer on cylindrical dural sac and its contents. Changes in this part contribute immensely to central stenosis.

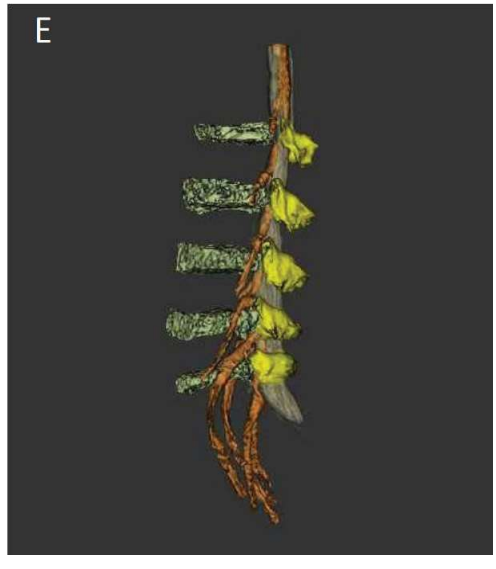
Images used from Kamogawa J, Kato O, Morizane T (2016) Three-Dimensional Visualization of Ligamentum Flavum Relative to the Affected Spinal Nerve Root by MRI/CT Fusion Imaging: J Pain Manage Med 2: 117. Copyright: © 2016 Kamogawa J, et al. Under (cc)





These image set 1 A B C D are clear enough to show upper foraminal lateral ligamentum flavum. This portion causes exiting root involvement in upper sub pars zone. Right image B is where bony components anterior and posterior are removed. Orange is nerves, yellow is the ligamentum flavum that goes obliquely up in upper foramen. If we watch closely lower zone involvement of the root by lower edge of ligamentum may also see in additional images that follow. We need to study clearer images of lower zone in 3 parts in large numbers.





This C D above also highlights the important portion that is below disc level. We can clearly delineate portion that is indeed important for root involvement. Images may be maginified to pin point area needing our attention wrt ligamentum.

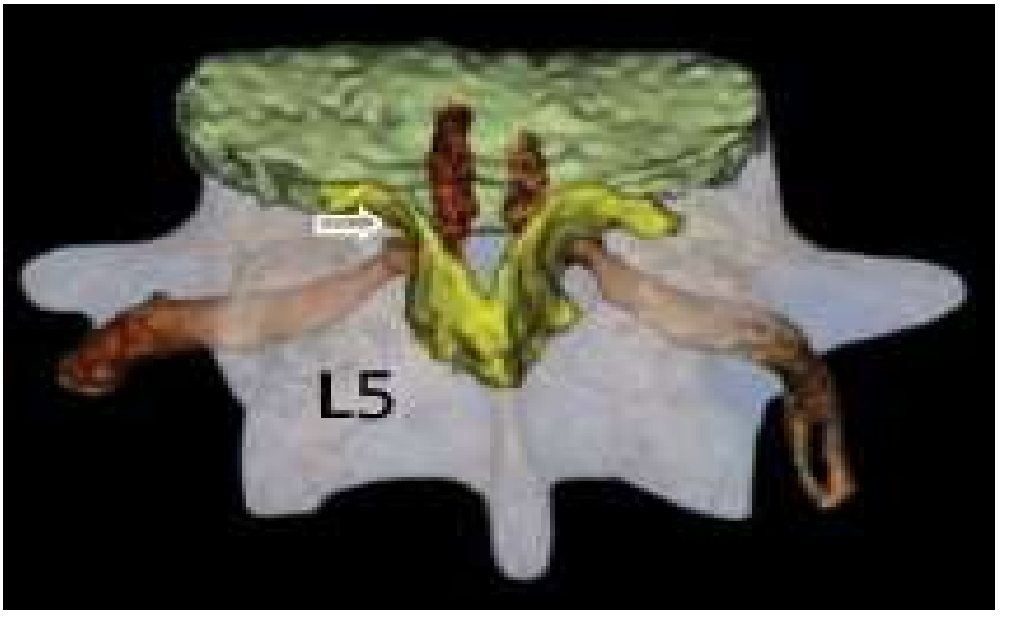
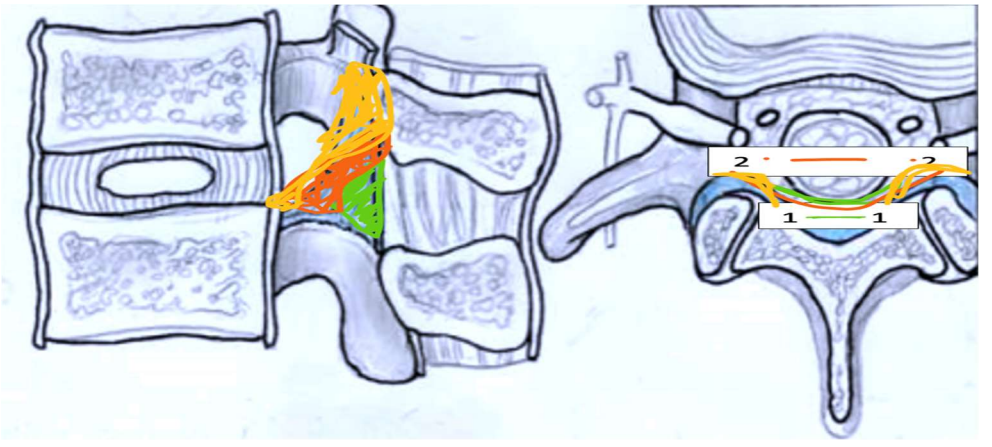


Image 2 above Coronal facet inclination is more involved as cause in stenosis than sagittal. A coronal facet makes transforaminal access easy but reaching medial wall of facet after undercutting ventral facet little more difficult. Unilateral symptoms are seen commonly due to compression of traversing root at root canal entry part 1 ventrally at floor of infradiscal area. Compression of cauda equina in jaws of pincer facet may cause bilateral symptoms.

3 In studies of ligament, we see 3 types. 1 green only interlaminar 2 interlaminar plus subarticular orange 3 laterally up to upper pedicle yellow. Type 3 is seen in 68% patients.

Image 3 A B Ligamentum flavum of 3 types 1 2 3 G R Y



Type 1 green between 1 and 1 this is interlaminar central part. The ligament is mostly deficient in midline. There is retrodural space between dura and ligament. Type 2 orange between 2 and 2 is subarticular medial part. Type 3 yellow extends beyond 2 and that is lateral part. Ligamentum flavum bridges window between two vertebral arches. Subarticular and lateral ligamentum excision without bone removal is not possible in open surgery as lateral is lateral to facet edge and away from our interlaminar entry.

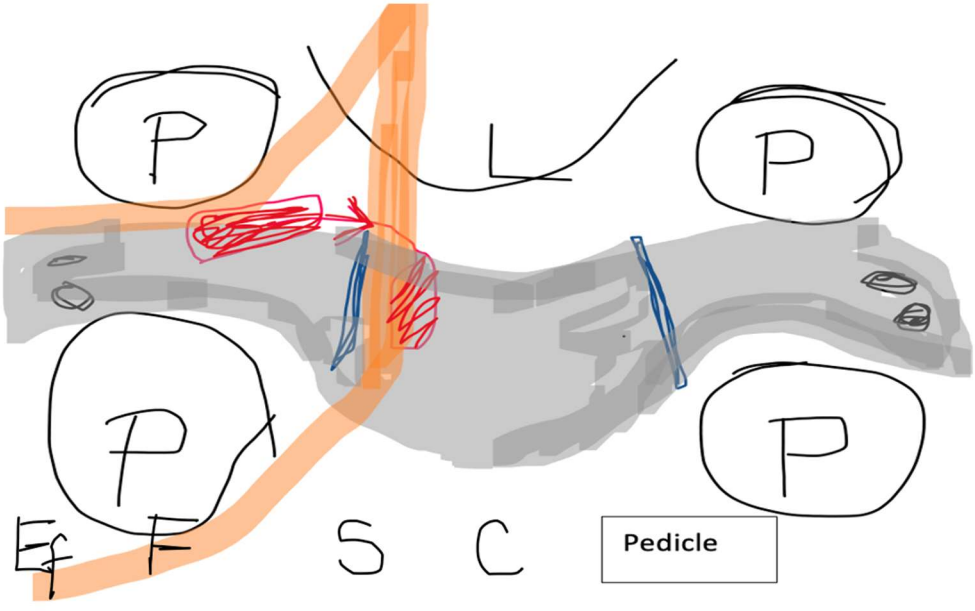
Image 4 sag cut for ligamentum mid to lateral to facet edge.

Mid sagittal cut shows the interlaminar ligamentum flavum bridging window. Specimen shows disc disruption and ligamentum flavum hypertrophy.

4 Ventral dissection by OKUDA describes 5 types of ligamentum anatomy and how it causes compressive neural symptoms in foramen roof [lateral ligament] and central canal [subarticular on edge of the facet and medial part on medial facet wall]. This is a rare but significant ventral study of the ligamentum flavum and is a must read.

I would very strongly recommend reading this paper with attention.

Image 5 Schema ventral study of ligamentum flavum



Orange nerve root path, red access u to m above SAP, Gray is ligamentum, blue is facet ridge, black dots in lateral ligamentum is perforating artery above and dorsal ramus below, c central s sub articular , f foraminal, e f extra foraminal.

Schematic diagram of the ligamentum flavum in ventral dissection per okuda. In subarticular area we can see the edge of the facet that forms pincer edge. We can also see the whole ligament is contiguous, that is once we gain an access to area above SAP we can follow it caudally on inner surface of the facet as shown by arrow. We can also access lower zone by landing in infradiscal area.

5 Lateral parts of ligament are covering tip of SAP and subpars and are unknown to traditional surgery as it is in hidden zone of Macnab.

6 Affected root and shape, location, and pathology of the LF is difficult to see in "hidden zone" of Macnab and the "far-out zone" by Wiltse using routine imaging methods.

7 LIGAMENTUM FLAVUM can be seen well all along its course in a coronal oblique view. This modality of coronal oblique imaging is available to all MRI set ups using S I JOINT imaging protocols. It cannot be highlighted with radio opaque dye. This needs to be seen with ventral perspective too.

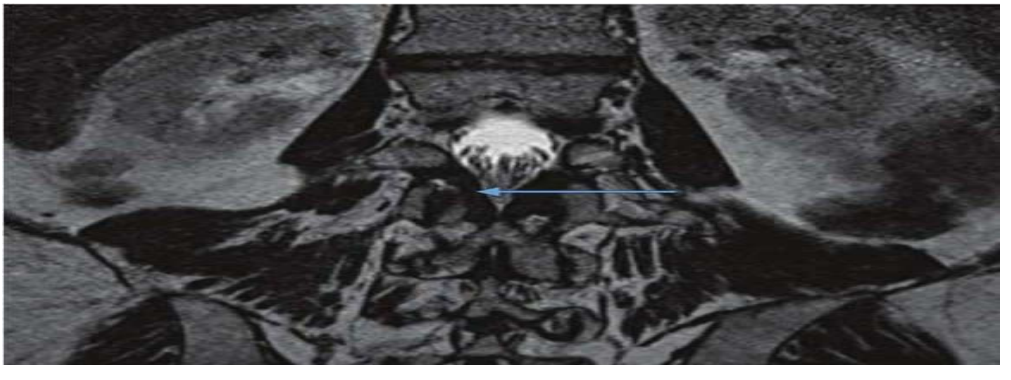
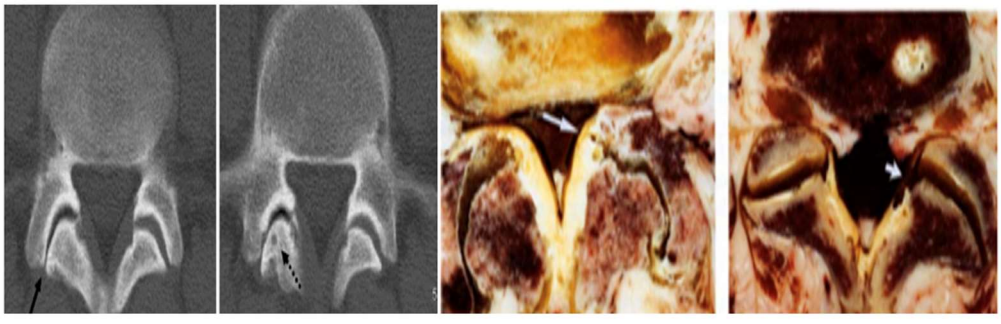


Image 6 Coronal oblique view showing ligamentum flavum midline to pedicle above, blue arrow is facet edge, central canal border.

8 If we have long standing compression of roots, preoperative presence of continued numbness or motor deficit as foot drop is a bad prognostic sign. It is associated with residual leg pain/ numbness and gait disturbance even after intervention.

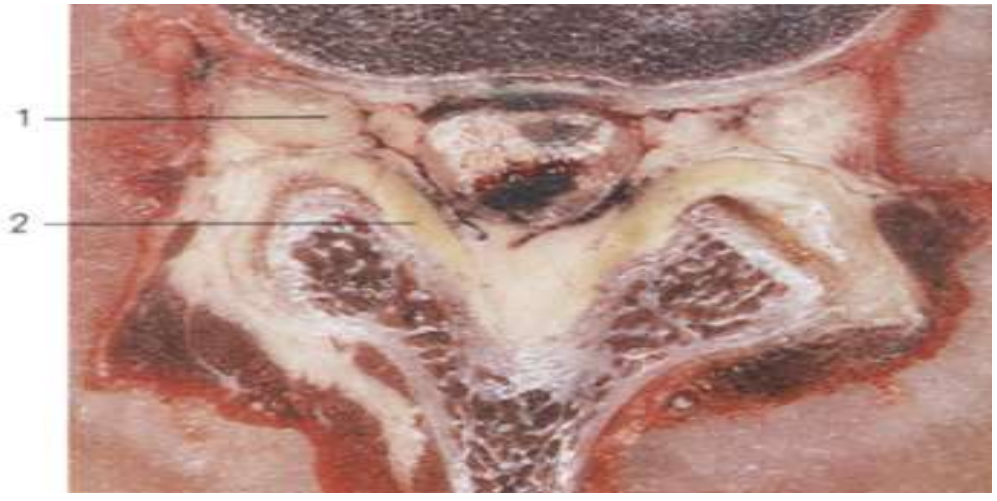
9 Ligamentum in central canal that is medial portion is attached to ventral surface of upper lamina and 2 slips on upper edge or border of lower lamina. The deeper of the 2 lower slips may be more symptom generating due to its likely [unproven] closeness to neurovascular tissue. This matter is not fully resolved yet.

Image 7A B C D Facet capsule and ligamentum seen on edge of lamina.



Our concern is ventral surface of the facet and not dorsal capsular changes. White arrows in image 59 shows subarticular changes. Left image shows type 2 ligament. Image on right is type 1 probably a distal caudal cut.

Posterior midline portion is difficult to reach through foramen but does not cause symptoms and is away from nerve roots whereas lateral subpars is important and is not reached by open surgical interlaminar access.



10 Image 8 upper zone. 1 is DRG 2 is lateral ligamentum flavum can be removed without removal of bone.

Some anatomical reports deny presence of ligamentum flavum in lateral recess part 2. It is very odd to see mandatory open surgery to expose traversing root by medial facet removal. It seems mandatory medial facet removal is more for visual comfort than significant root decompression. We must visualize it better for understanding and to be effective in solving claudication.

Focus on LF

It is not possible to enhance LF with contrast media in images. Ligamentum flavum may cause more of narrowing of the lumbar spinal canal than the disc in spines axially loaded to simulate sitting or upright standing. LF thickness correlates with age, disc space height, angulation, and facet joint osteoarthritis.

Hypertrophy is associated with segmental instability and severe disc degeneration, severe facet joints osteoarthritis, and sagittal facet joint orientation.

3 How to read a CT scan to detect targets in stenosis

Axial cuts from head down. Set of 5 images from L5S1

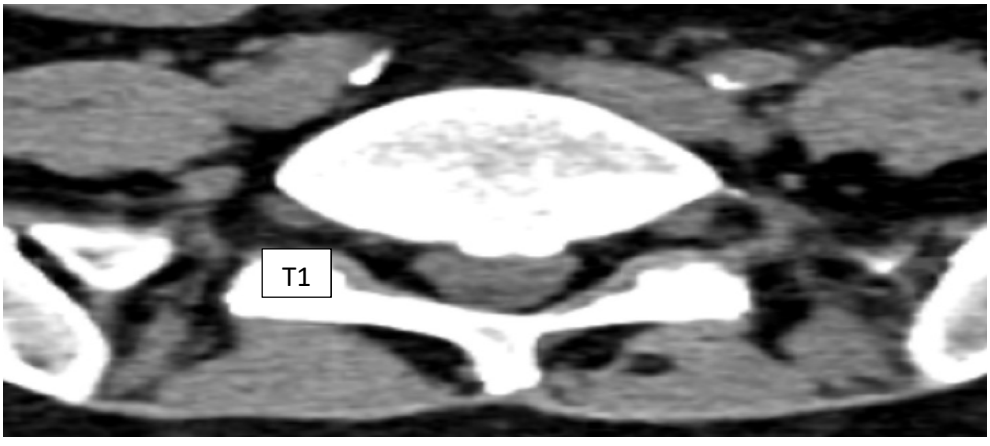


Image 1 upper zone axial CT. Shows IAP, lamina some lateral ligamentum flavum, open bilateral foramina.

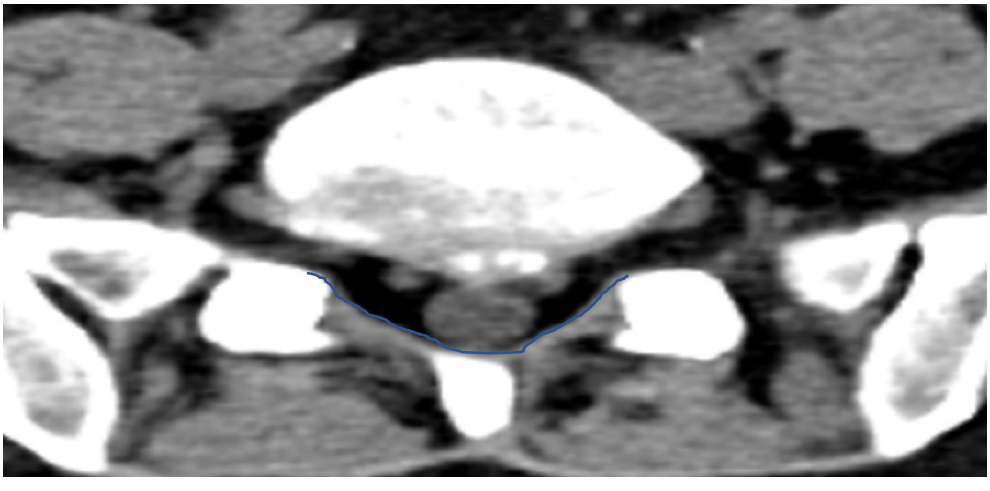


Image 2 middle zone image, showing real posterior wall that is interlaminar window ligamentum flavum. In traditional thought ligamentum here is always shown in a BONY v. That is only if cut is at lower lamina that has attachement of upper ligamentum; that you will see bony V.

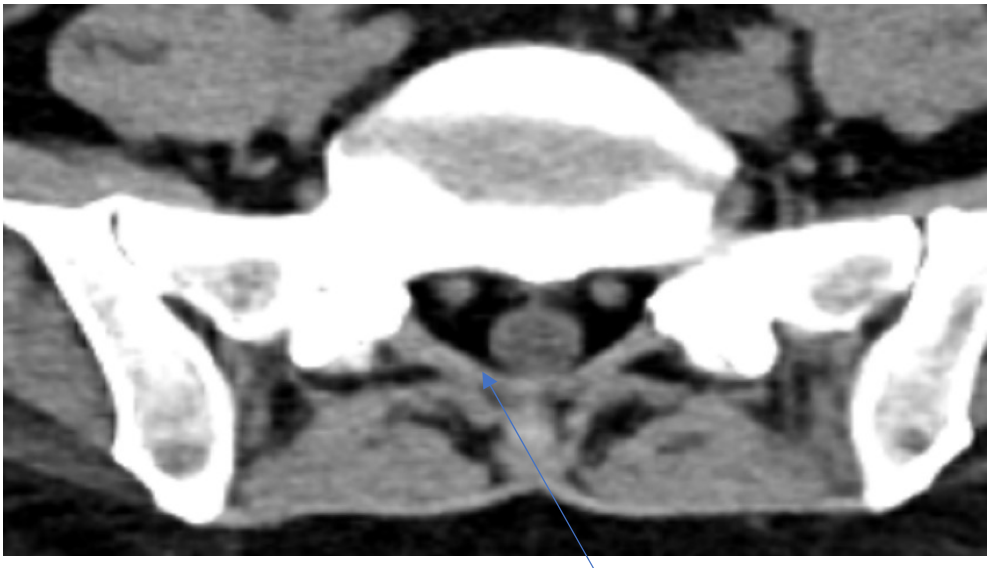


Image 3 of the middle zone lower than image 2. We can see traversing roots leaving thecal sac. Posterior wall is still ligamentum flavum and not bony lamina.L5S1 has a wide interlaminar window.

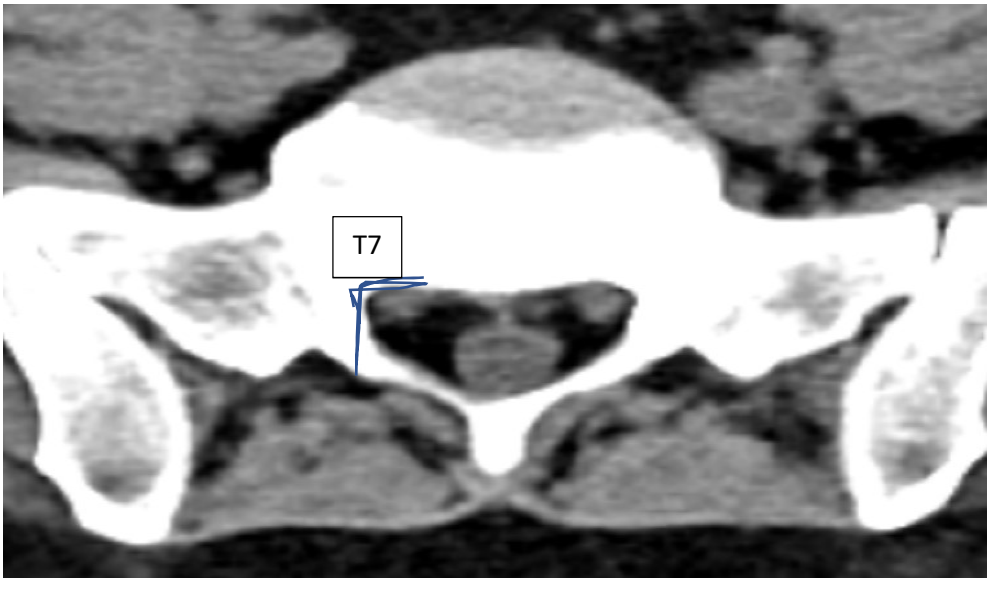


Image 4 upper lateral recess or lower zone , showing lateral wall of the recess, pedicle. The lateral recess shape is like c here.we see a midline septum anterior to dural sac.

Above level is L5S1 image 5. This is lower zone lateral recess part 2, where we see lateral wall of the recess that is pedicle is seen more like < > than a C. Traversing roots are seen well.

Now for L45 where we apprecaite the zones and also realise the targets.

Set of 6 images at L45. 2 images for each zone.

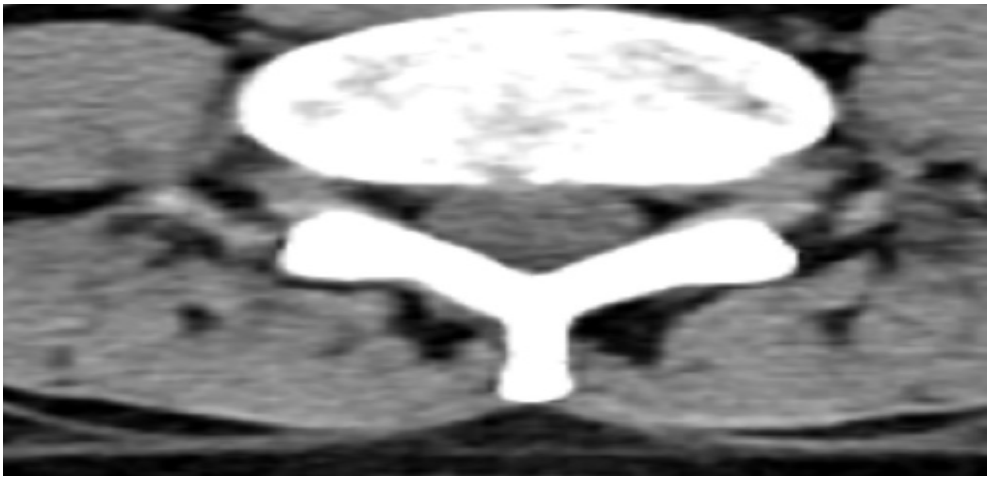


Image 6 upper zone lateral DRG in open foramina. NO DISC no facet joint. Pars may show lytic defects in this zone.

Image 7 shows lateral ligamentum shart of SAP tip.This is our access for middle-upper-middle zone strategy.We are below exited nerve.

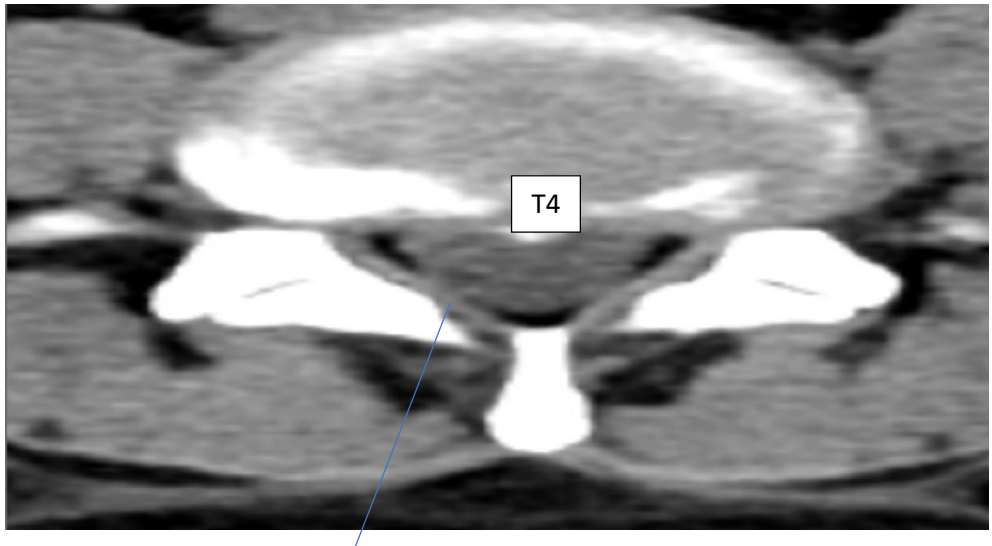


Image 8 middle zone canal level shows bilateral facet joints, 45 degrees, we clearly see the ligamentum flavum going up to subarticular level. If we had a coronal oblique image may be it would have shown lateral part

.

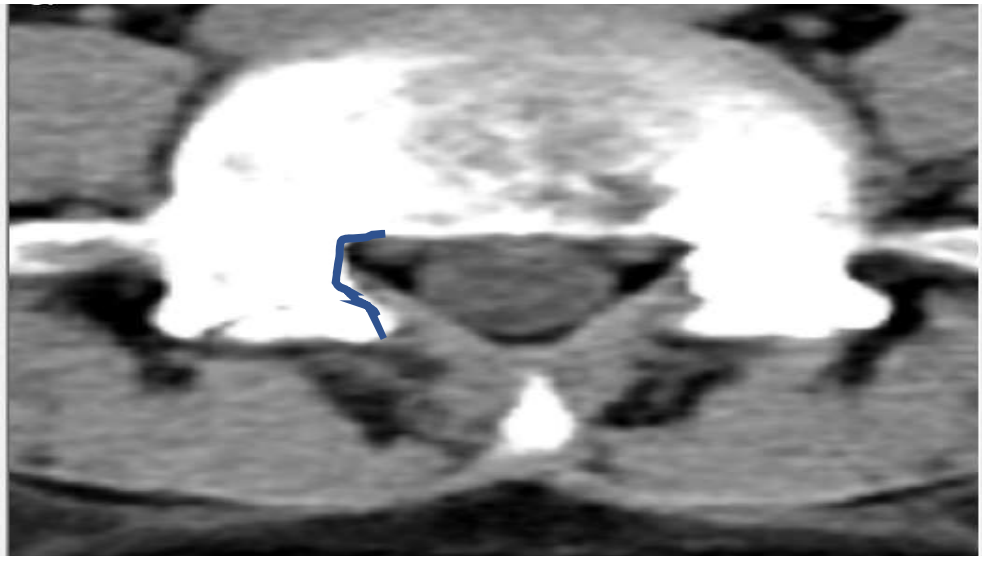


Image 9: We are in caudal most part of middle zone, discal end plate level. We see ligamentum flavum in posterior wall. More of Sap is seen and facet joint is seen. As we see lower zone part 1 here and next cut.

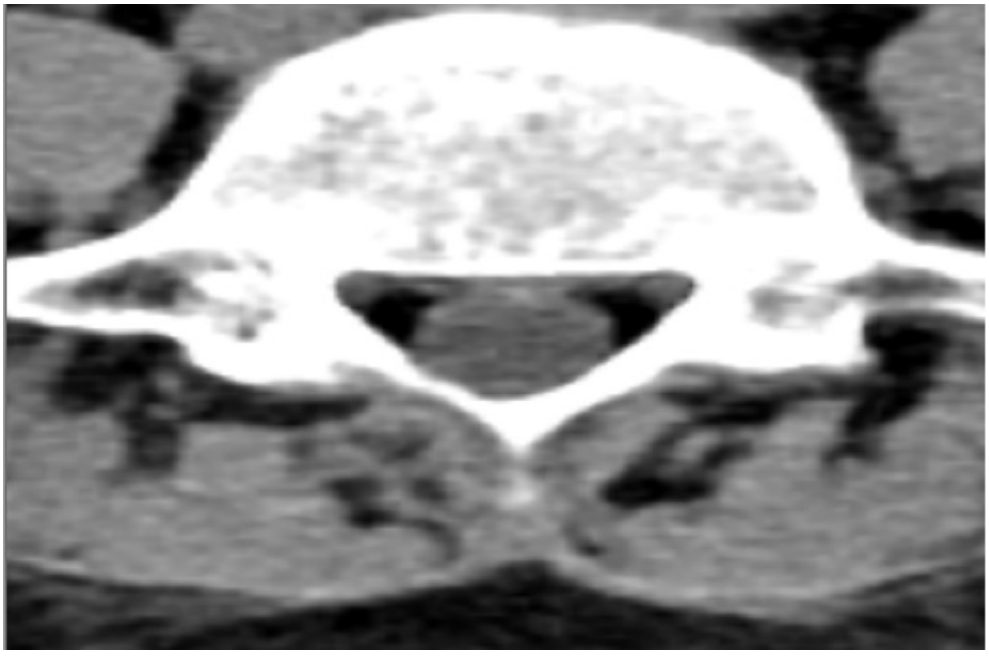


Image 10: Part 1 lateral recess, pedicle wall is like C. Root is travelling in pedicular groove.

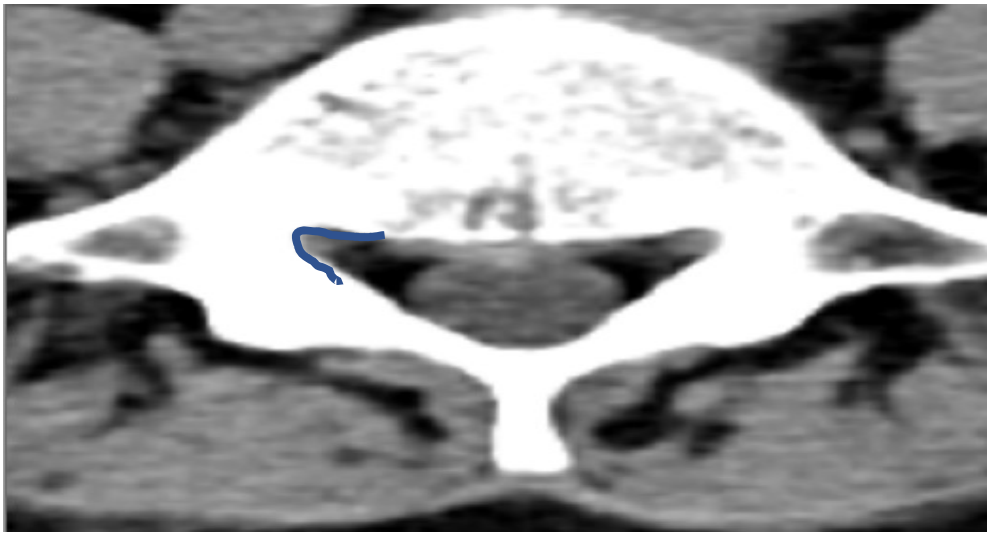
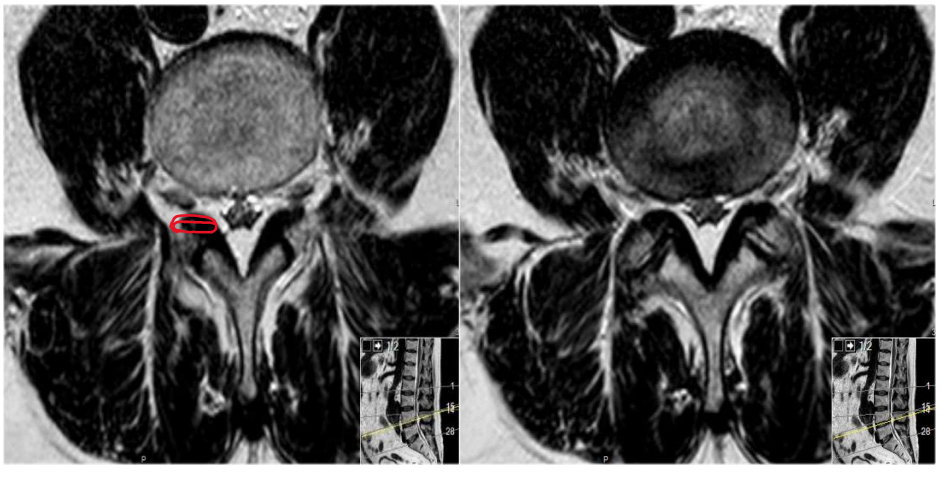


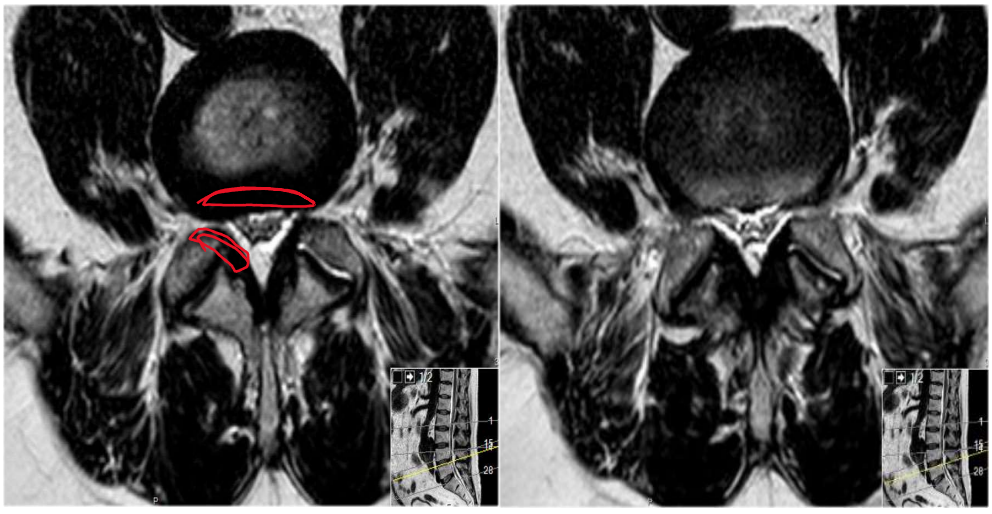
Image 11: This image is lower zone lateral recess part 2 here pedicle wall is now like < >. Travelling roots are seen more close to pedicle. Facet joint forms posterior wall and ends at lower level of part 2.

How to read MRI images for targets in all 3 zones:

Upper zone 1 2, open foramen, no SAP, but DRG in foramen. Ligamentum dorsally sub pars and in canal. 2 is distal portion of upper zone. Targets 0 denotes absence of facet joint or disc in upper zone, 1 LF and axillary tissue in failed back, 2 Pars lytic defect

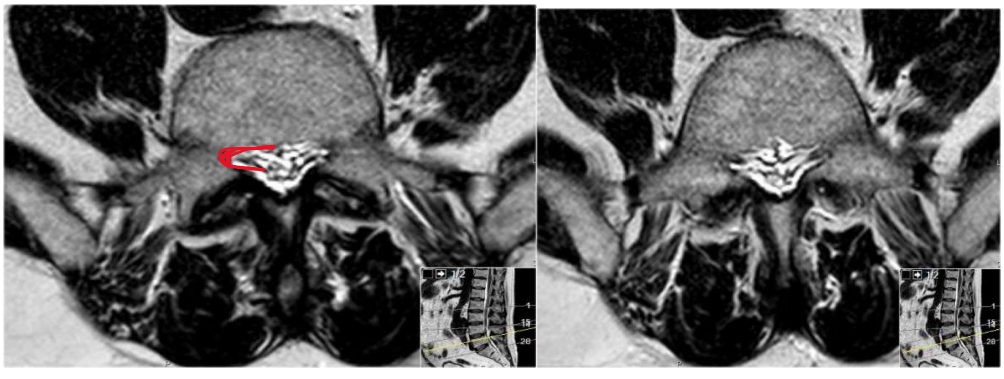


Sections 3 4 showing middle zone. No nerve in foramen, ligamentum on facet face, facet joint with 45 angle, and its edge imp Disc concavity. Targets 3 facet medial face 4 disc post annulus 5 foraminal g knot



LOWER Zone: Lateral recess below.

Section at lower endplate level at beginning of soft tissue lateral recess. We see lower attachment of ligamentum flavum on laminar edge and facet border. Image 5,6



This image above beginning of pure bony lateral recess. Targets 6 ventral to nerve root part 1 of lateral recess, 7 dorsal to nerve root from lower pole of facet in part 2 lateral recess, 8 facet cyst.

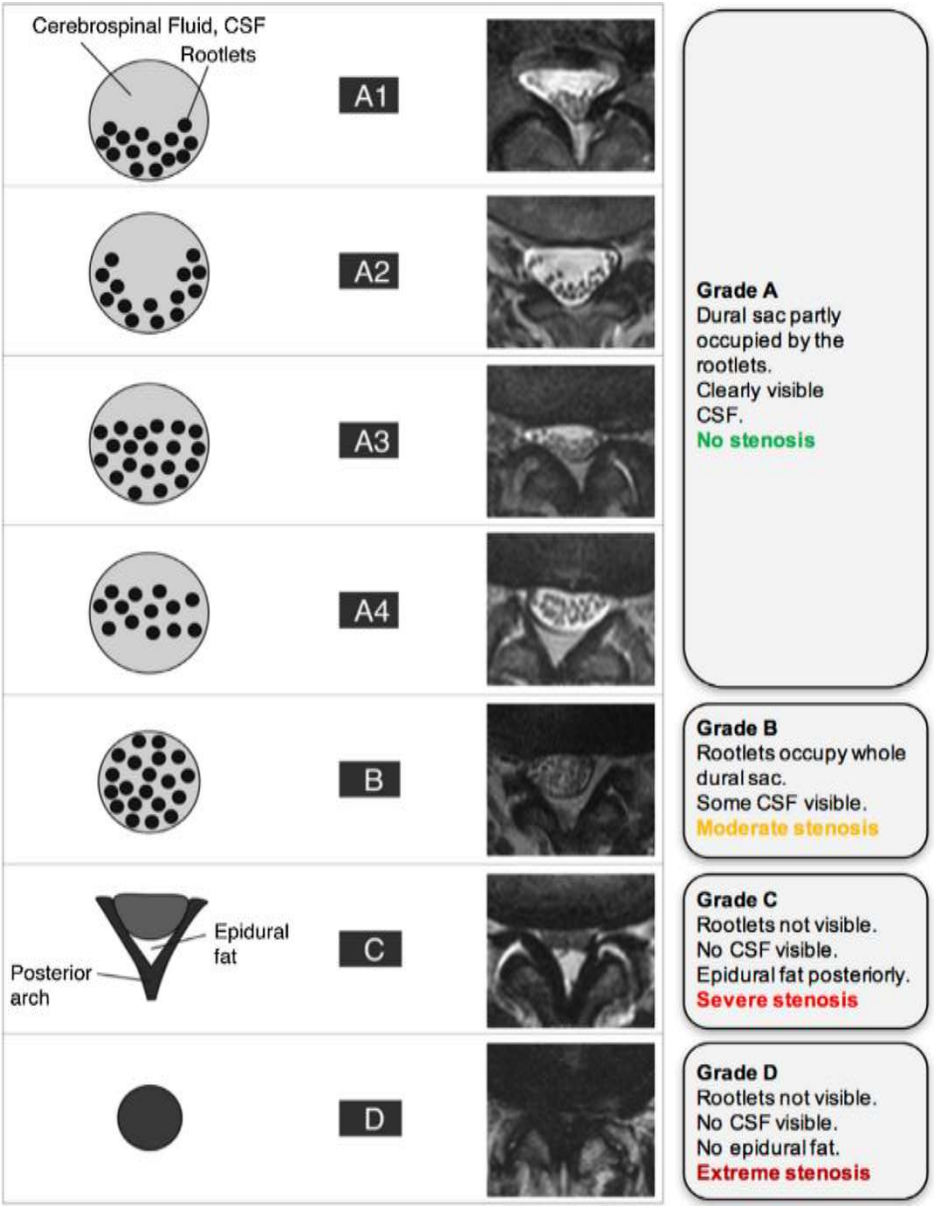


IMAGE 24 classification of lumbar central canal stenosis.

A is central canal stenosis classification. B is middle Canal Zone cuts. Showing facet inclination, cut at mid disc, inter radicular thecal sac, root in root canal, ligamentum flavum forming pincer. Roots settling dorsal in supine patient.

3 The middle zone: THE BASICs principles of surgery T3, 4, 5

When we land in middle zone as a part of access to lumbar canal stenosis we initially want to build up a mental imagery of ventral perspective and lateral perspective to upper zone and lower zone as seen from our landing spot in foramen lower part, in lateral canal. These images will show us where our targets are and how close we are.

We have graduated from ssula stitchless spine surgery under local anaesthesia ™ to three zone stitchless spine surgery under local anaesthesia. TRESSULA.

Images will show ventral view of middle zone roof highlighting remote midline lamina, oblique ventral view of upper zone highlighting lateral roof that may add to symptoms with lateral ligamentum flavum, medial interlaminar ligamentum and its attachment to ventral surface of the lamina in lower zone roof that has significant symptom generators namely lower pole facet in part 2 of lateral recess.

These are images of a functional spinal segment with 2 osseous rings and disc in between [disc removed in the model]. This imagery can be supplemented by left foraminal views of upper zone anterior and posterior wall view and lower zone anterior and posterior wall view. The previous anatomical images showing one single vertebra does not show the facet joint, posterior wall in middle zone and other relations of relevant structures namely facet margins and ligamentum flavum in all 3 zones. We will then look at 8 targets marked in these 3d bony model images. We have 3 zones with 3 targets each.

Upper with T0, T1 axilla, T2 pars

Middle T3 medial facet, T4 disc, T5 foraminal g knot

Lower Zone T6 anterior ventral wall part 1, T7 posterior wall part 2, T8 synovial cyst that comes from facet margin generally in lower zone.

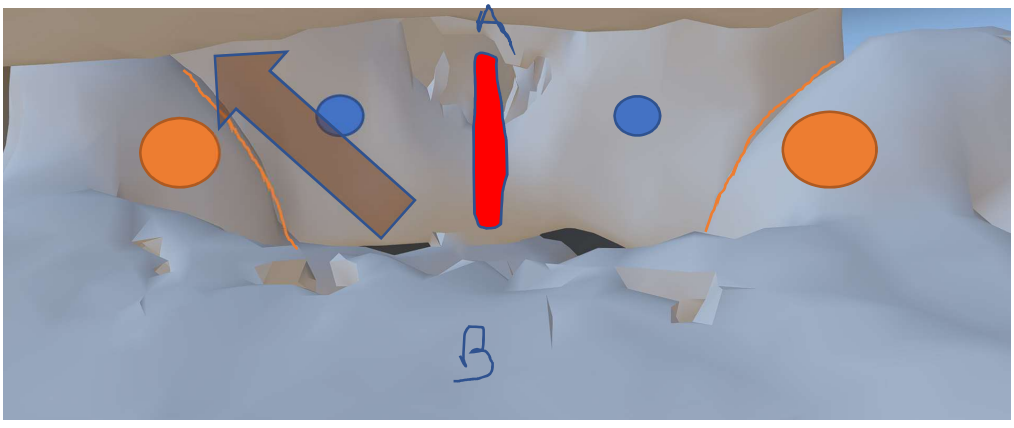


Image 1 Ventral view of the middle zone roof.

This view is taken in a model with disc removed. We see both facet joint edges. Ventral or SAP is seen clearly and dorsal to it the IAP. In middle zone if we look at horizontal plane parallel to disc then posterior interlaminar window is below level of disc. In image we see lower margin of the lamina from above.

Orange dot is SAP both sides are marked.

Orange lines mark facet edges, this is pincer jaw. This may compress the thecal sac in central canal and result in claudication or if severe chronic cauda equina syndrome.

Blue dots is IAP or the lamina from above. We know posterior wall of middle zone is formed by lamina from above and IAP joining SAP from vertebra below in facet joint.

Mid line red is far away from the thecal sac.

Ligamentum flavum brown is shown on one side of midline. In middle zone here we only see ligamentum flavum in its upward and outward spread starting from midline, covering subarticular and then sub pars area.

Both vertebral bodies are shown with letters A above B below.

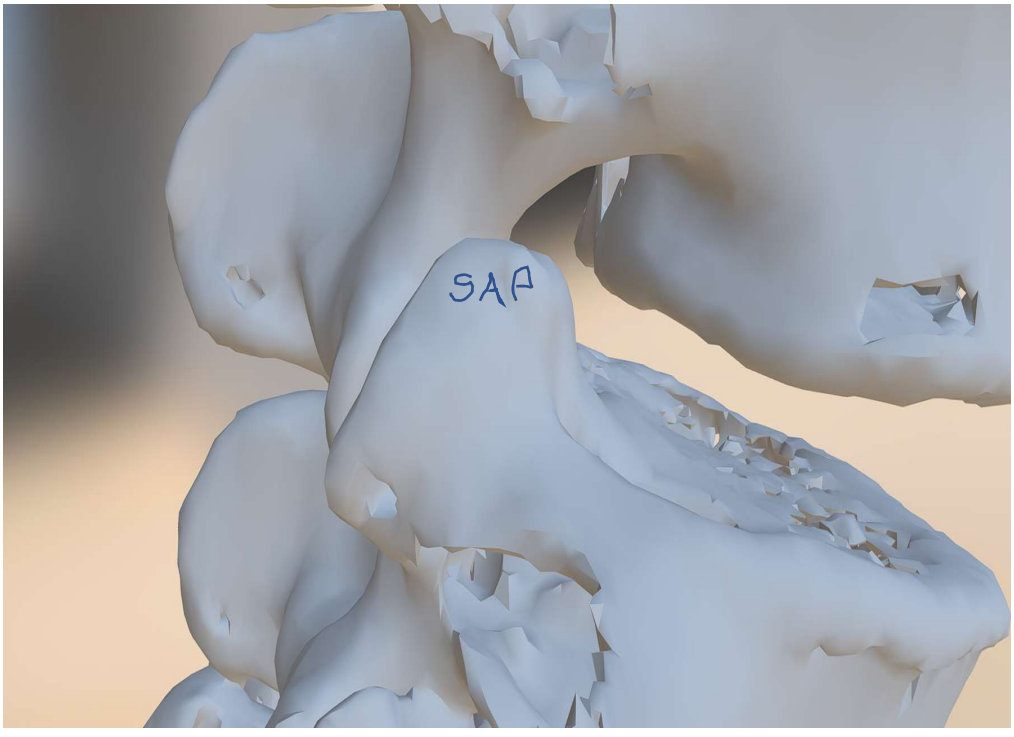
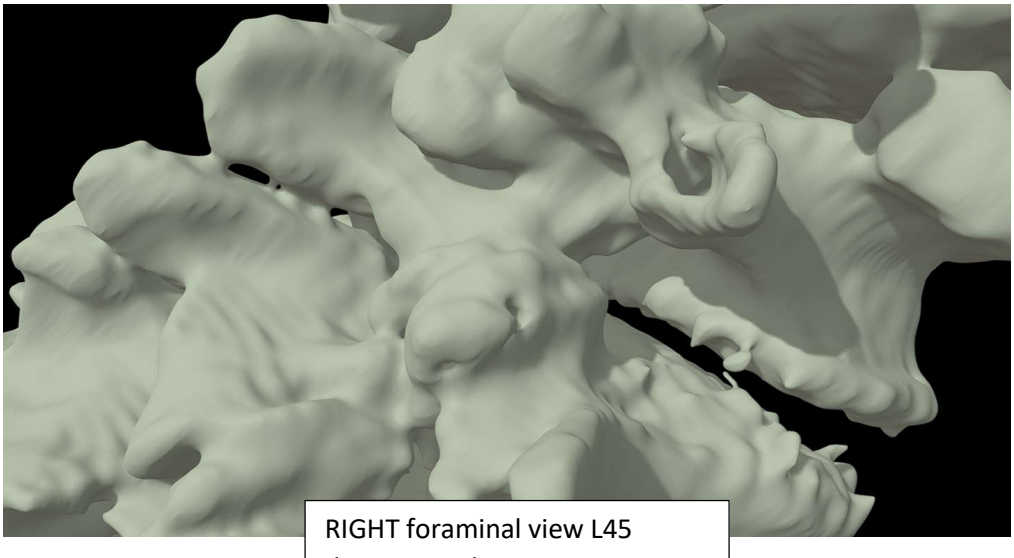


Image 2: Right foraminal view of middle and upper zone.

SAP tip is in line with inferior end plate. We have lateral ligamentum flavum covering sub pars area. Disc in front has been removed. Our landing is on sub facet area or lateral facet face.

Image 3 similar view in a degenerated segment.



RIGHT foraminal view L45 degenerated segment.

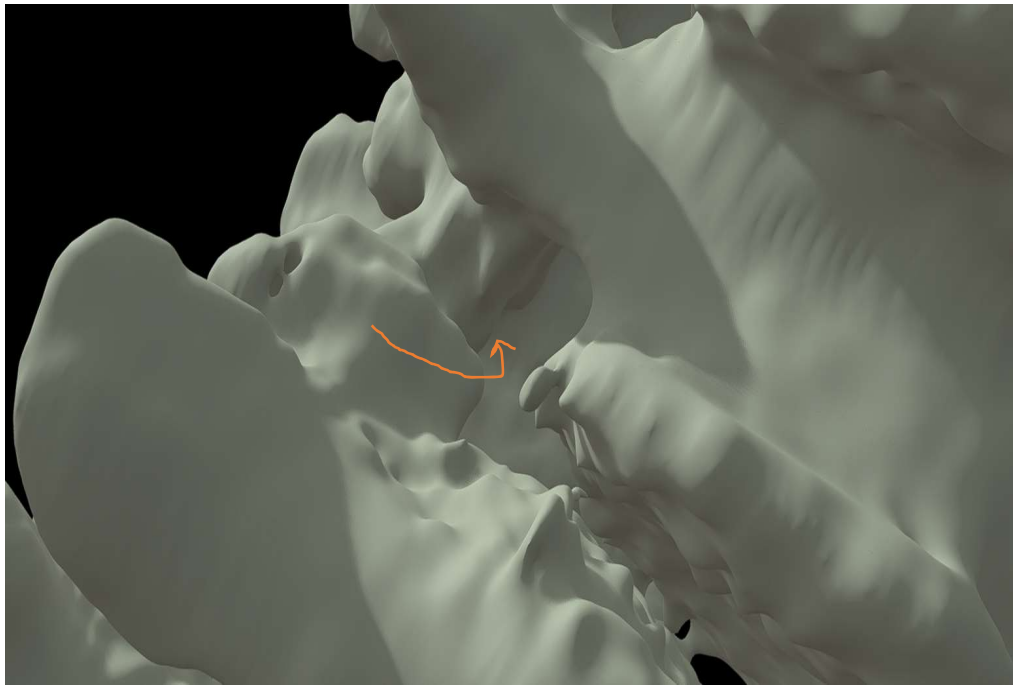


Image 4: Rt. foraminal oblique view looking towards foraminal roof.

In middle zone our work relates to facet edge and the medial facet face marked by arrow here. Similar view in image next showing remote laminar midline. It also shows a close relation between Sap tip and IEL line, where G knot formation is common. X cross is pedicle above.

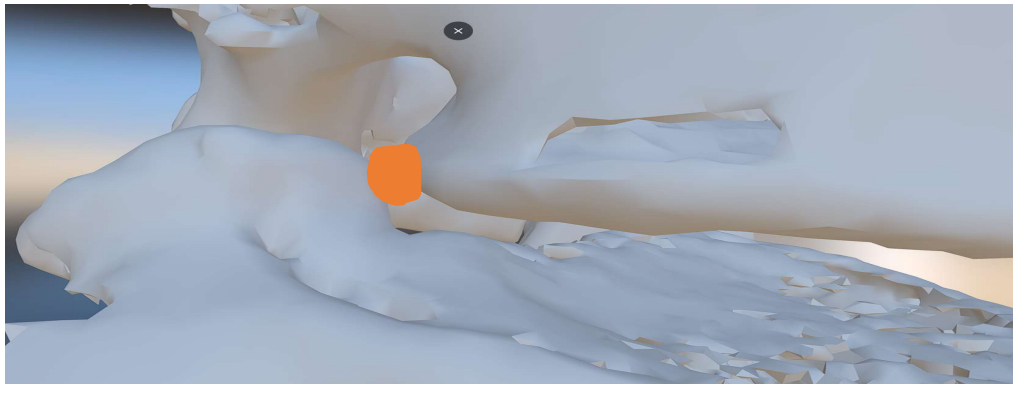


Image 5: Rt. foraminal view looking at roof. G knot location marked with orange dot.

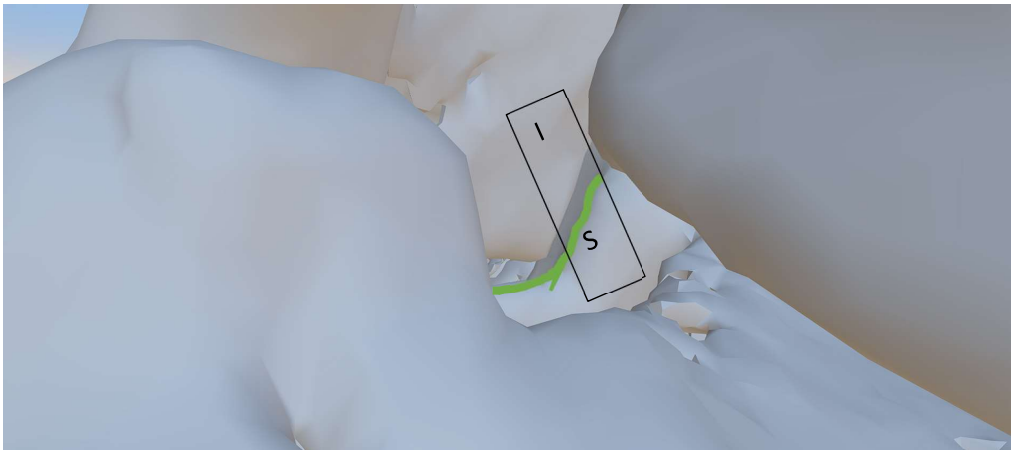


Image 6: Image is rt oblique foraminal view at L45 showing lower facet pole on opposite side.

It shows the green line that is facet edge, having ligamentum attachment. IAP is dorsal to SAP and facet seems to be at 45 degree. I is IAP S is SAP inside a rectangle marking subarticular area.

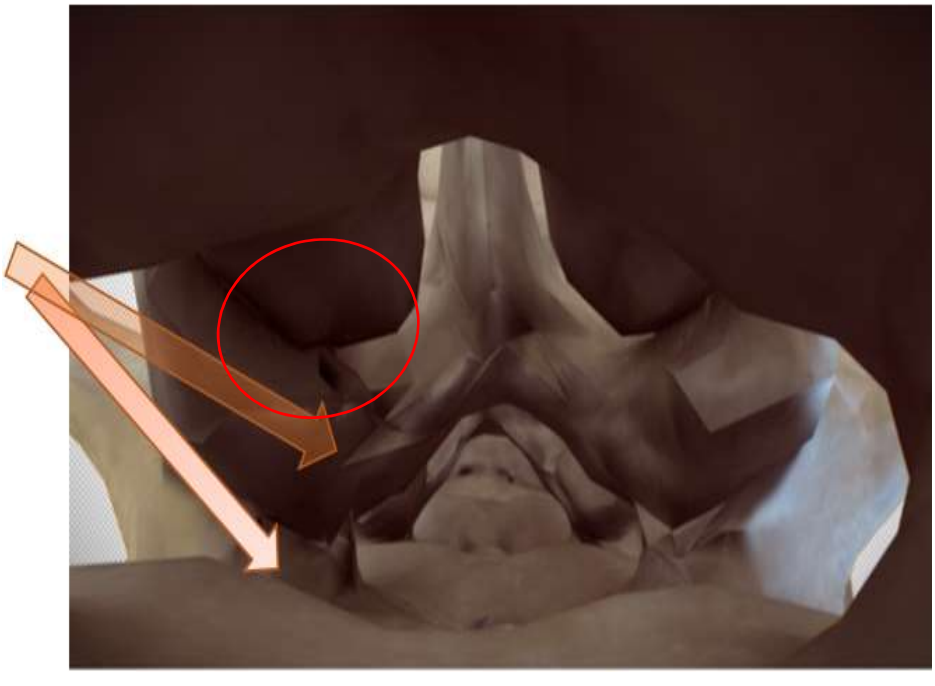
Degenerative cascade by Kirkaldy Willis mentions three stages of degenerative changes in functional spinal unit. [But it is silent on ligamentum flavum]. Stage of dysfunction characterized by herniations etc. stage of instability with micro instabilities and then natural stabilization. The instability stage gives tissue hypertrophy at disc margins, facet margins and in ligamentum flavum causing symptomatic stenosis in functional segment; and then SEGMENT may remain unstable or go on to auto stabilise.

Middle zone is interposed between two bony rings of vertebral body. It has MOBILE and dynamically CHANGING walls and structures. It covers "central canal". Posterolateral facet joint pincer in middle zone "LYING IN AN OBLIQUE PLANE" tightening around thecal sac more AT AXILLA causes stenosis. PINCER IS OBLIQUE NOT horizontal and its constriction at SAP in axilla is exaggerated by extension.

Bony rings and contents: Posterior parts of two adjacent vertebrae with flaval tissue between are seen sloping down in SAGITTAL cuts of middle zone. The axial section L45 level may include a part of lamina and spinous process of L4 i.e. upper vertebra. The facet joint is best seen IN AXIAL CUTS , with superior articular process of L5 vertebra forming anterior part of joint, and inferior articular process of L4 vertebra forming posterior part of the ring at middle zone. [Or in ventral view as in our model image 1]. Our targets in middle zone are T3 facet medial face T4 disc posterior annulus T5 foraminal soft tissue and related.

Our TFE for disc with inside out technique needs to be modified, as our target [red circle] is roof now. SHOWN by upward angulated arrow.

Image 7, 8 Medial wall clearance of ligamentum in interlaminar surgery and transforaminal surgery for neural decompression.



Canal seen in axial tunnel view above and targets below image as T3 4 5.

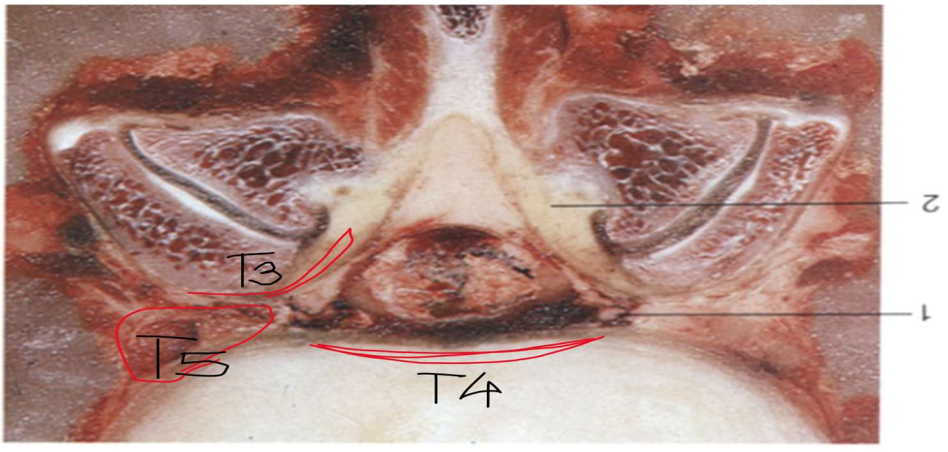
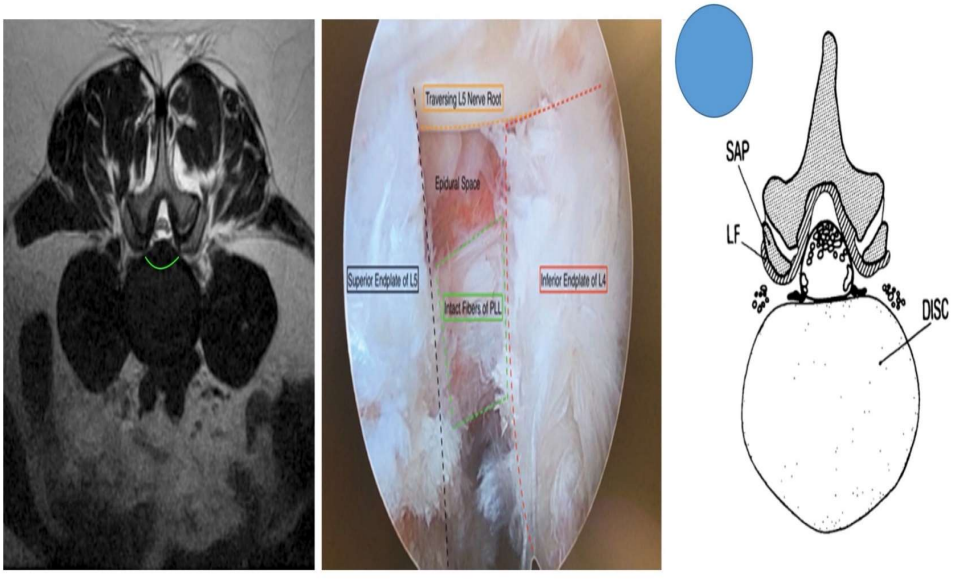


IMAGE 8: Axial cut at middle zone.

1 is root 2 is ligamentum. Midline ligament is unrelated to symptoms. Ligamentum covering facet joint and lateral part is symptom generator.

Image 9 A B C: Looking through disc at ventral epidural surface.

Intra discal landing is needed to work on posterior annulus but is inadequate and irrelevant for roof related work in stenosis. Trajectory needs a change towards roof. [As shown in image 7 above].



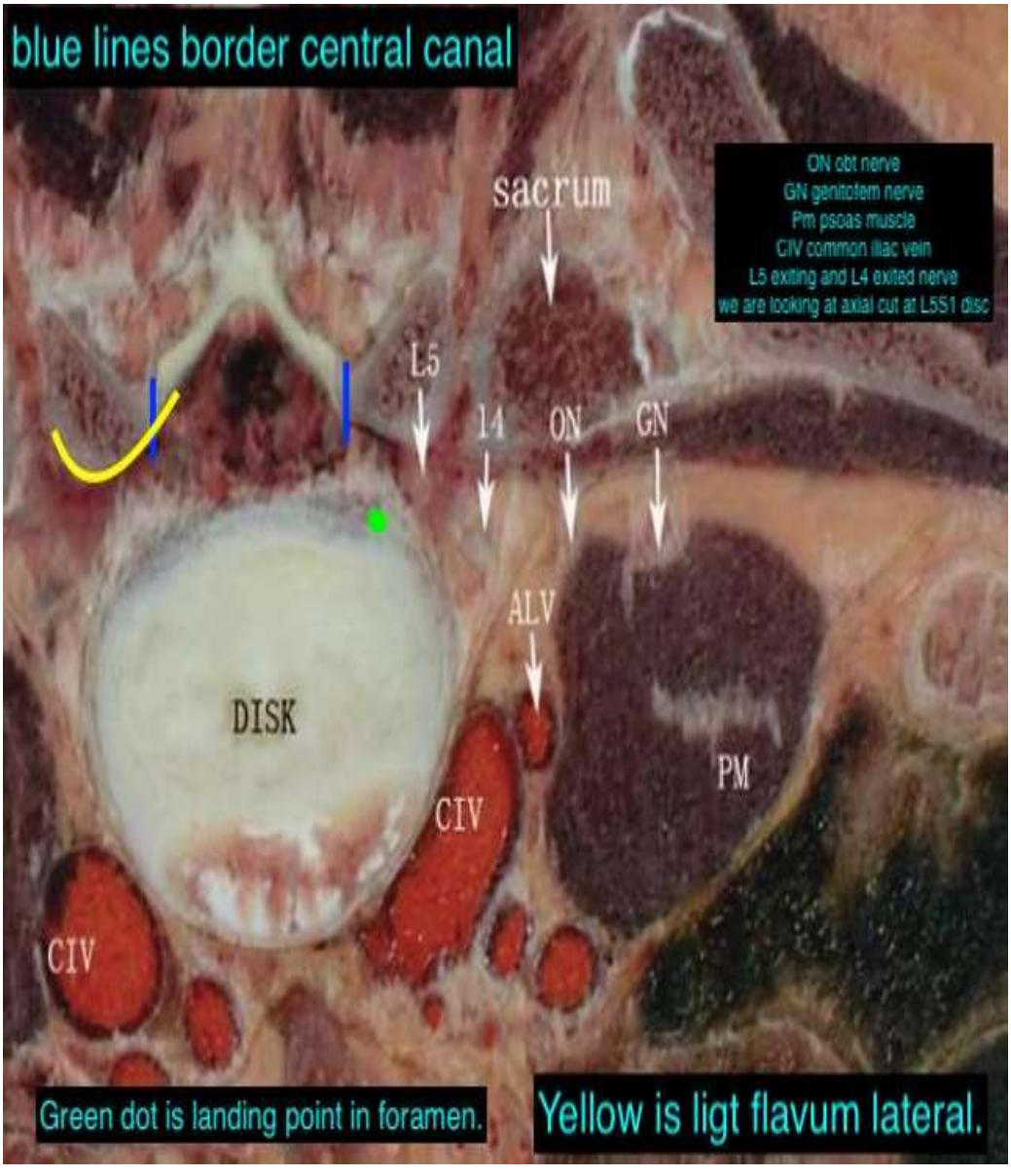
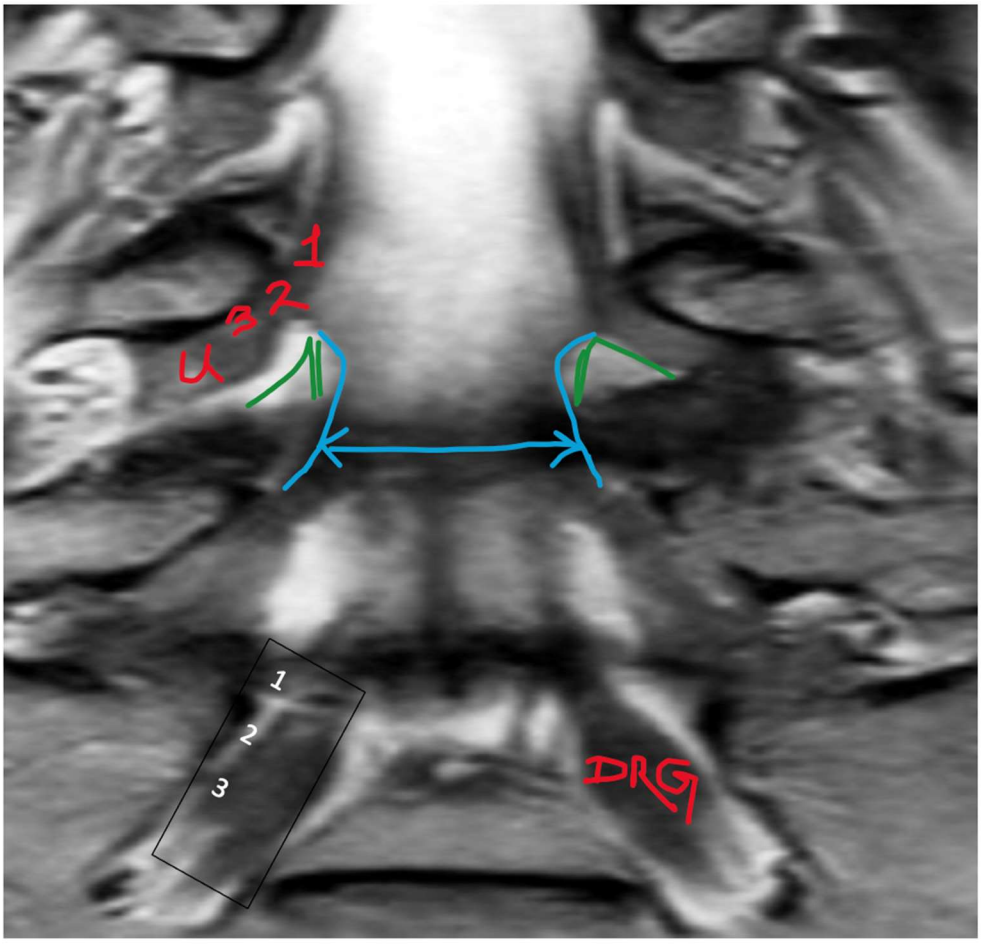


Image10 Target yellow on under and inner face of facets. T3

This image is to give an idea about change in trajectory needed to work on roof. We 1.change trajectory or 2.use an outside in access or 3.use bendable instruments or 4.use extraforaminal teku fulcrum to elevate our instrument working ends. From our standard green landing reaching yellow ligament is not easy.

Image 11 2 D coronal perspective, at mid coronal level.



We have here mental visualization of ventral perspective of posterior wall that is seen building up. We can see facet edge blue lines from sides covering up thecal sac. Central canal roof is facet to facet not pedicle to pedicle. Axilla is encroached by SAP tip green with its soft tissue cover in present image. Lower zone lateral recess parts 1 2 3 seen clearly as RED marks. Blue lines also indicate inter radicular part of the thecal sac.

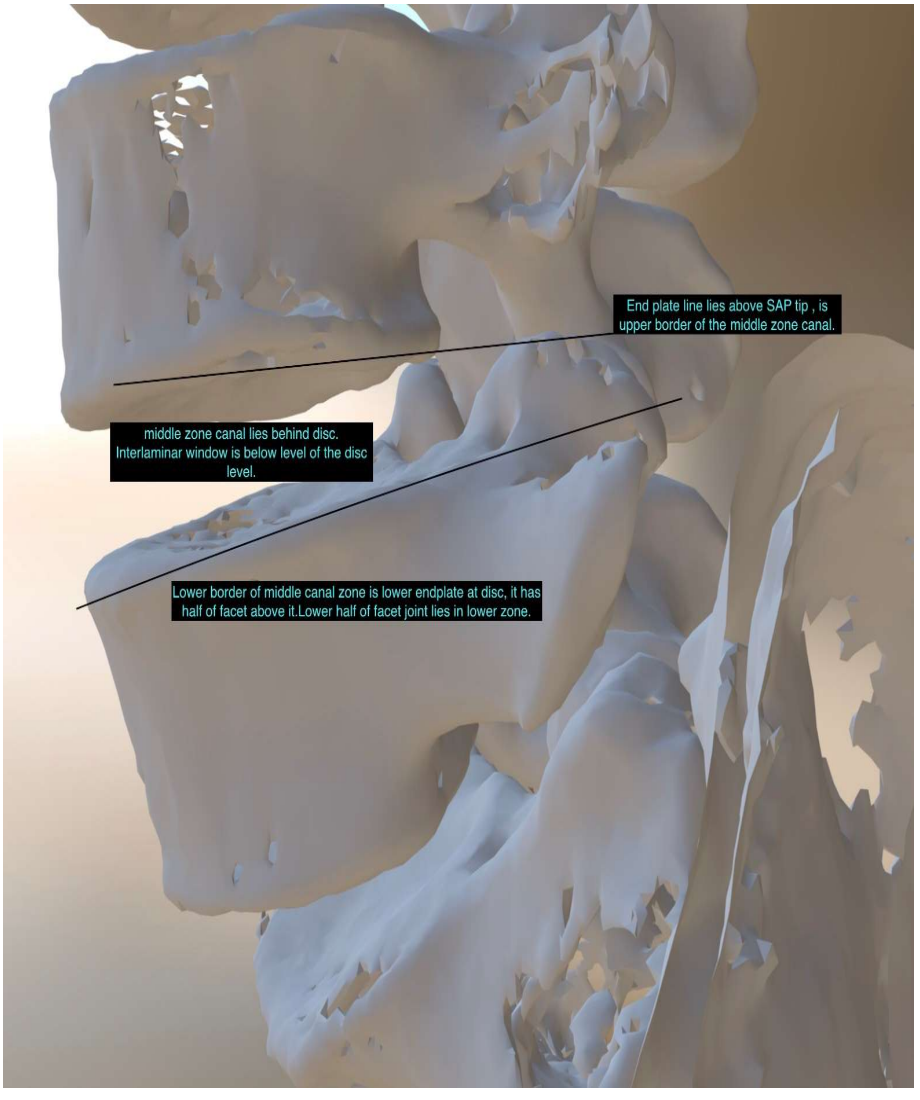


Image 12: Relation of lower foramen with central mid zone canal.

TFE Bilateral facet edge bone and medial face soft tissue removal around inter radicular part of thecal sac under vision is a solution for central canal middle zone stenosis. It may be easier than a blind fluoro guided cutting in outside in access. If facet joint is inclined sagittal may necessitate more undercutting; coronal may have more tissue

hypertrophy at facet margins and inner facet face. Coronal facet adds a trefoil canal profile. OUR target roof needs more mental visualization.

IMAGE 13: Ventral look at posterior wall of lumbar canal and Ligt flavum.

3 white arrows show our strategy. Thin white arrow is ventral facet under cutting plus small curved arrow is entry to middle zone from above SAP tip. Additionally THICK white arrow is access to lower zone and root canal part 1 2. SEE absence of ligamentum flavum over lower pole. A

combination of these strategies is used to treat lumbar canal stenosis in all 3 zones. Orange lines are facet edges.

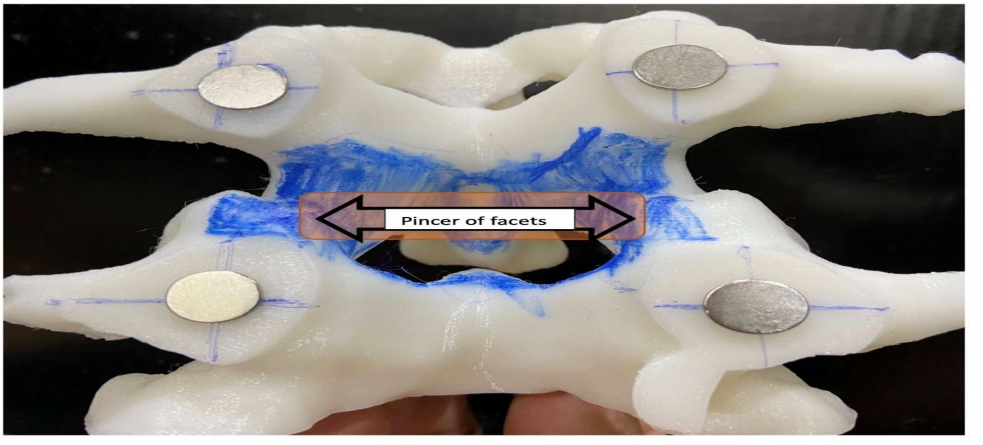
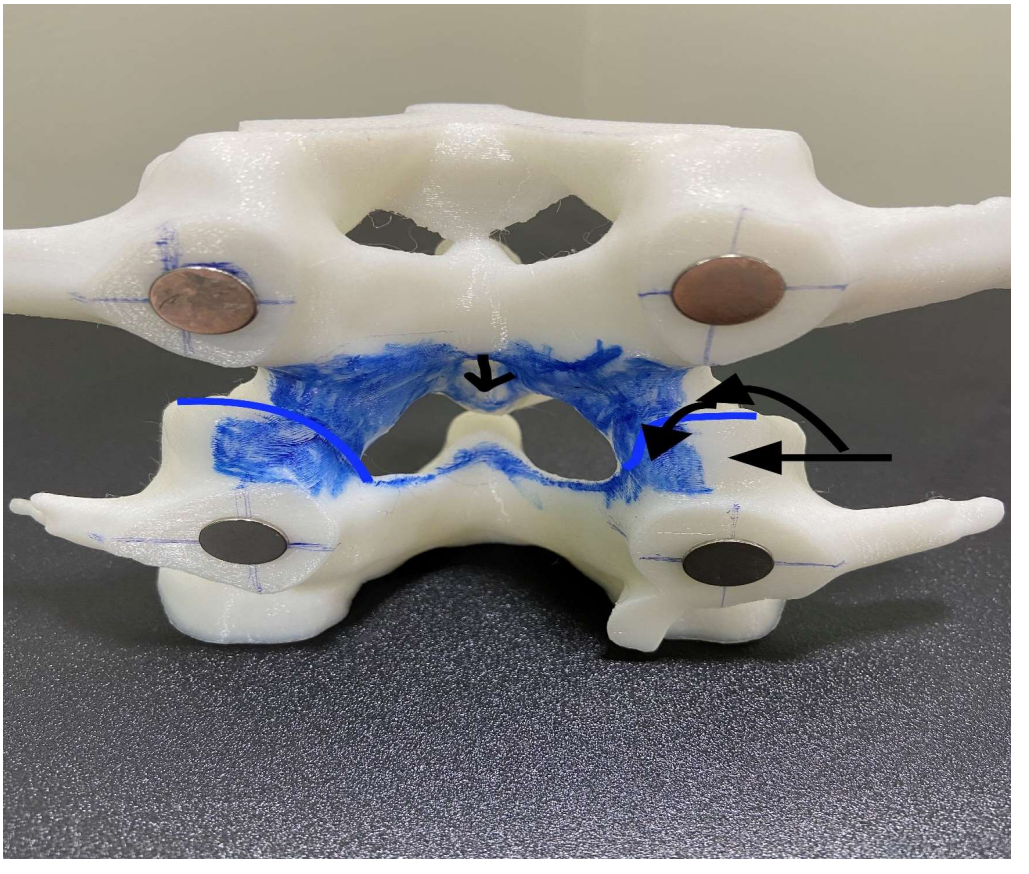
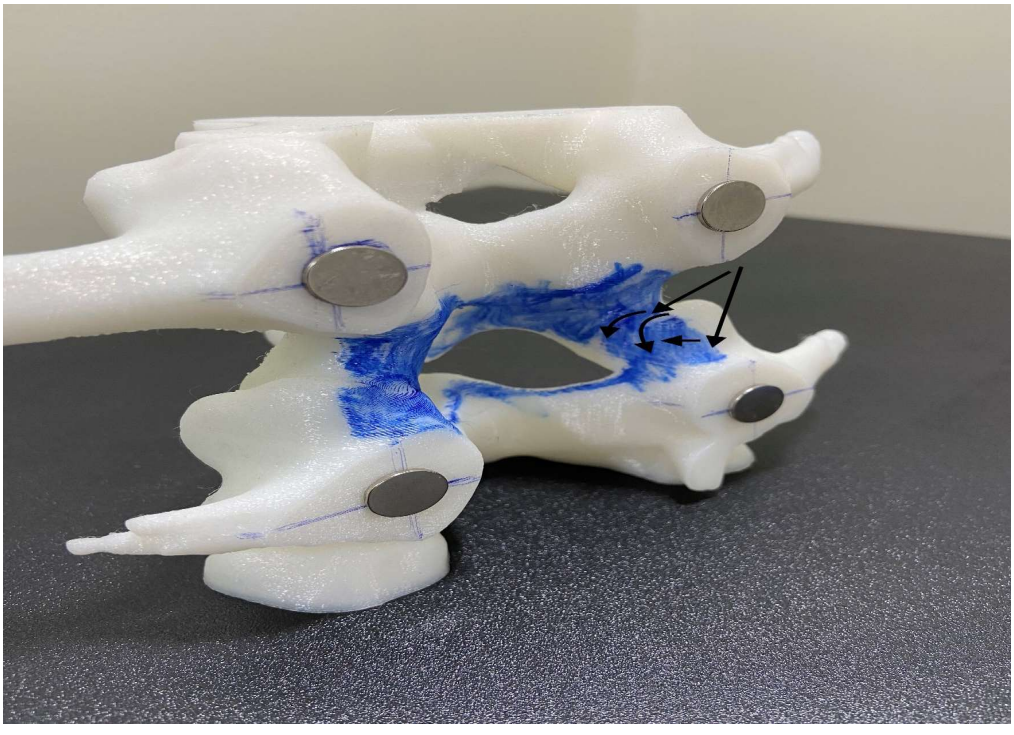


IMAGE 14 A B C: We can see the steps of reaching middle zone under and above SAP for the pincer of facets.



B central canal roof seen in model and surgery schema.



C. Access above Sap and onwards to medial facet face. Arrows. Shown in plastic model of ventral walls of the canal. Blue marking is ligamentum flavum, interlaminar window is seen without ligamentum Cover. Model is a 3d printed L34 1.5x of the patient data.

Model prepared by Dr Ankit Madharia, pedicles have metallic inserts. Posterior arches have been cut through pedicles.

Dural sac and root sleeves: Dural sac has a rounded shape in upper zone. At the L4–5 disc level root sleeves begin to form at its ventrolateral angles. It is important to highlight intrathecal sloping traversing root is guarded by the facet joint lying lateral to it.

Epidural fat and veins: The retrodural fat pad is very prominent at the disc level, and there is also fat ventrolateral to the dural sac extending into the lower foramen. Epidural veins are between the disc and the

dural sac at L5-S1. After draining the segment, veins join the ascending lumbar vein. OUTSIDE FORAMEN

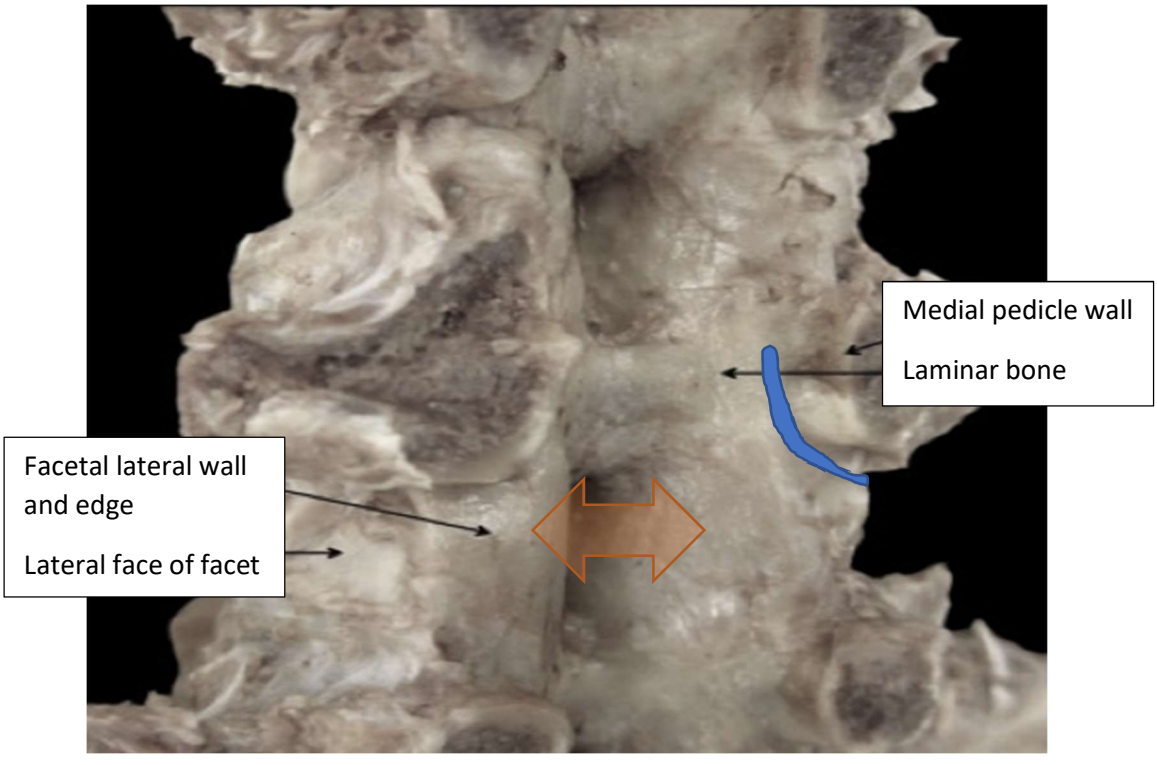
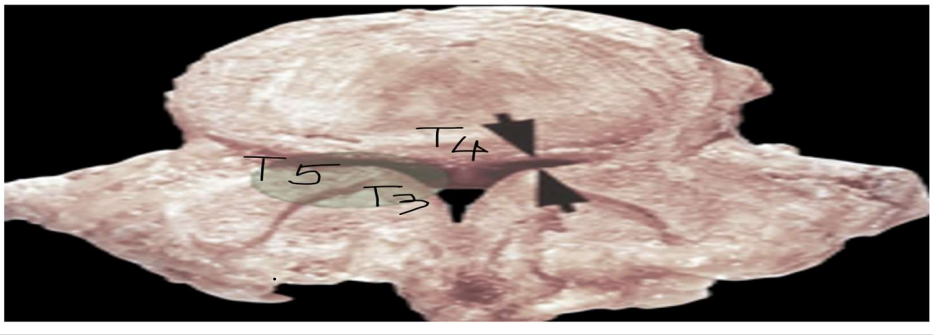


Image 15 cadaver model: facet edge that is under cut during bony foraminoplasty. THIS IS PINCER JAWS. Image16 Axial cut shows facet joint edges with very narrow central canal [green edge] and lateral recess [black arrow]. A Benz sign.

We see narrow laminar angle and solid orange arrow is central canal width. We can see the groove along medial wall of pedicle that is root canal. Marked blue.



Soft tissue: Anteriorly concave posterior annulus of disc and PLL lines MIDDLE CANAL zone. Laterally canal opens into rectangular lower narrow part of foramen. Sublaminar and subarticular middle zone central canal continues out as lateral canal in lower foramen. It has no nerve in LATERAL PART. Some variation is expected with inclination of the facet and laminar angle. Soft tissue build up at disc margins, facet margins or subarticular and lateral UPWARDLY SLOPING ligamentum flavum is better appreciated in coronal images as pincer tightening over the cauda bilaterally. We may NEED TO access both sides to decompress the sac adequately.

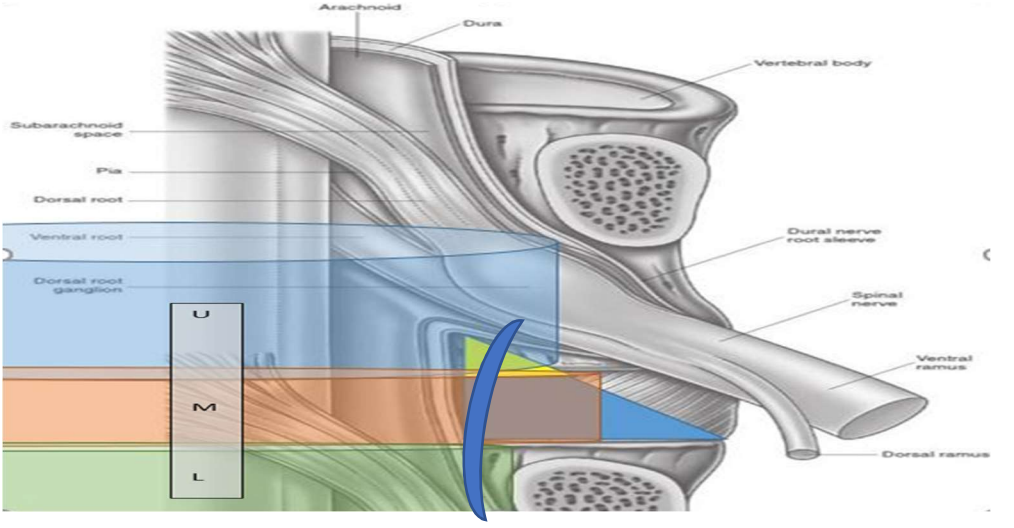
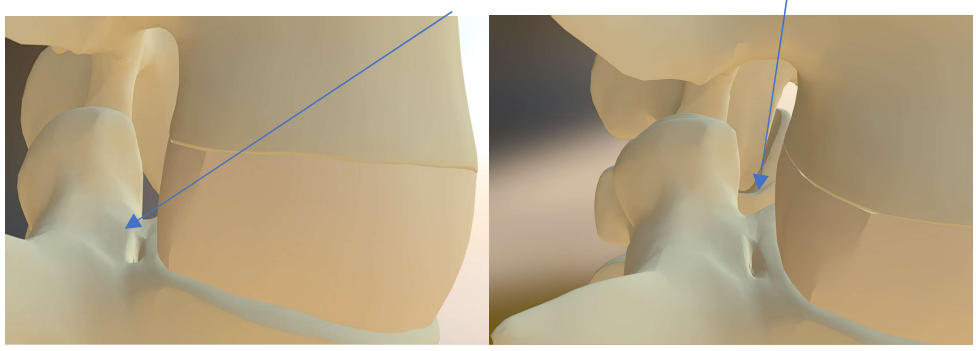


Image 17 Significance of facet medial face and edge.

Facet joint blue bar including both SAP and IAP as bony partition between interradicular portion of thecal sac and foramen outside and exiting root cephalad to it and traversing root leaving in a sleeve caudal to it. Our lateral decompression is partially removing this partition wall between central and lateral canal. We do it by landing in mid zone lateral canal; work on SAP tip and soft tissue cone and at lower notch work ventral to root and then if need to dorsal to it at lower pole of facet.

Facet lower pole is farther down at bisecting line across mid pedicle. Root is lateral to facet edge here in lower zone lateral recess. [Facet joint ends at mid pedicle bisecting line level.]

Image 18 ABC Bony facet lateral surface seen, and inside face of other side.



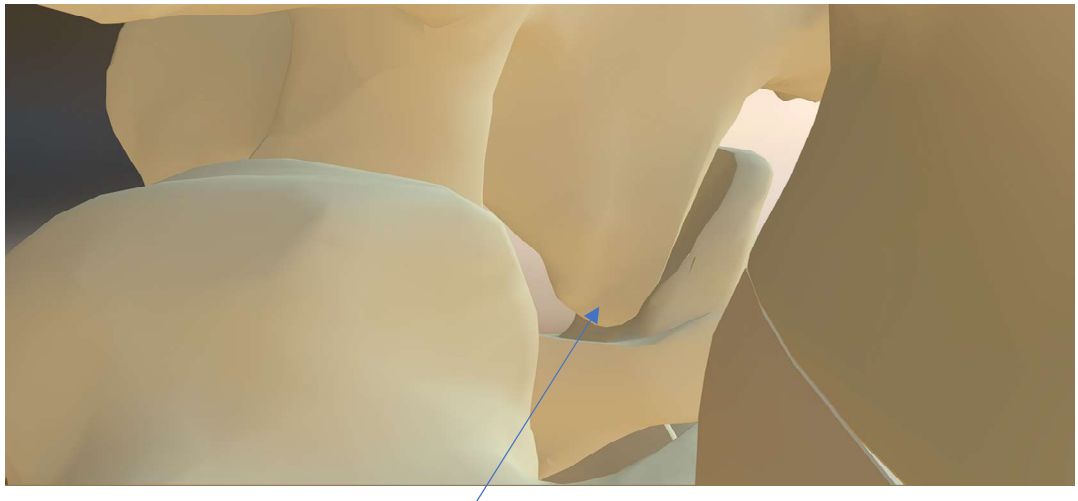


Image 18 c: Facet edge and lower pole view from opp. side foramen.

Key here when looking at ventral face of opp. facet lower pole is ligamentum flavum goes up obliquely. Facet capsule may be hypertrophied, but as ligamentum is attached to edge of lamina and may cover articular lower pole as it ascends up towards pedicle above its presence or absence on lower pole, lying dorsal to part 2 of root canal is still debatable. Inadequate information exists. When treating middle zone we have to confirm that lower facet pole is also adequately decompressed.

TARGETS: Symptom generators T 3 4 5

Anterior: Disc herniations, partially chronically healed, collagenised, hardened, loss of concavity of the annulus, trapped nuclear fragments, osteophytes at either margin of the disc. All disc herniations T3: type 2 nucleus with annulus or 3 nucleus plus annulus plus end plate fractured piece that collagenizes. Disc herniation that may be chronic and untreated, Calcified or ossified annulus of old surgery, Adhesions tethering traversing roots, old surgery, partially resolved herniations. Leaking or blocked annular tears in central annulus with trapped nuclear fragments. Peri dural membrane that is now proposed to have characteristics of synovium may contribute to inflammatory causes here all discogenic causes of stenosis will have chronic BACKACHE.

Postero Lateral: hypertrophy of ligamentum flavum on inner wall of facet T4 and subarticular part acting like a pincer crowding cauda equina traversing nerves in central canal and giving bilateral symptoms. Smaller inter facet distance with acute laminar angle makes it more stenotic.

Lateral: G knot: T5 Soft tissue knot in foramen connecting SAP to lower endplate of cephalad vertebra with amalgamated soft tissue in foramen. Lower notch of foramen, part of lower zone, may also have soft tissue changes. [These form part of soft tissue lateral recess of lower zone part 1 target 6].

Posterior: Interlaminar window with its "medial" CENTRAL ligamentum is below level of disc SO MAY BE INCONSEQUENTIAL AFTER ALL. This point must be very clearly understood. Interlaminar window is not in plane of disc.

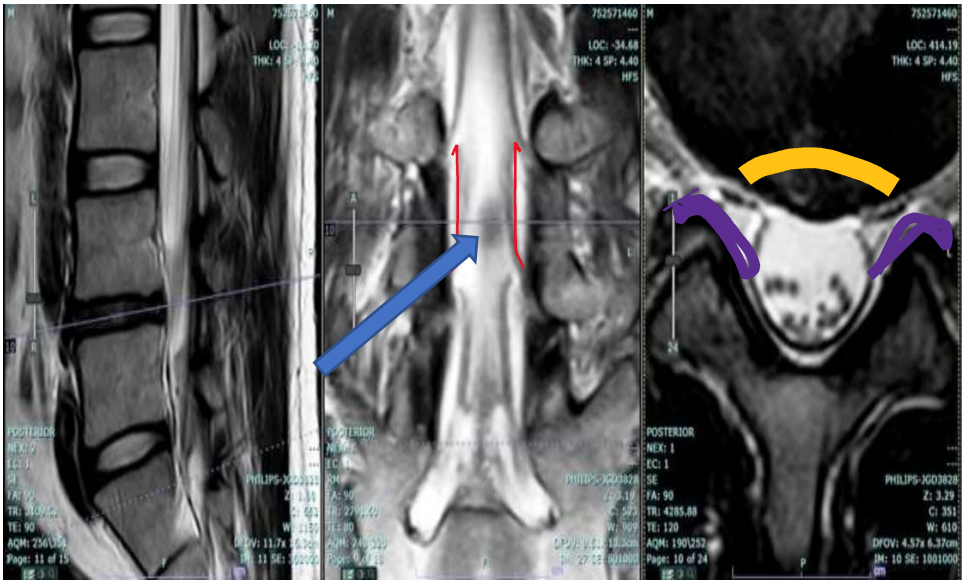


Image 19 classic middle zone cut.

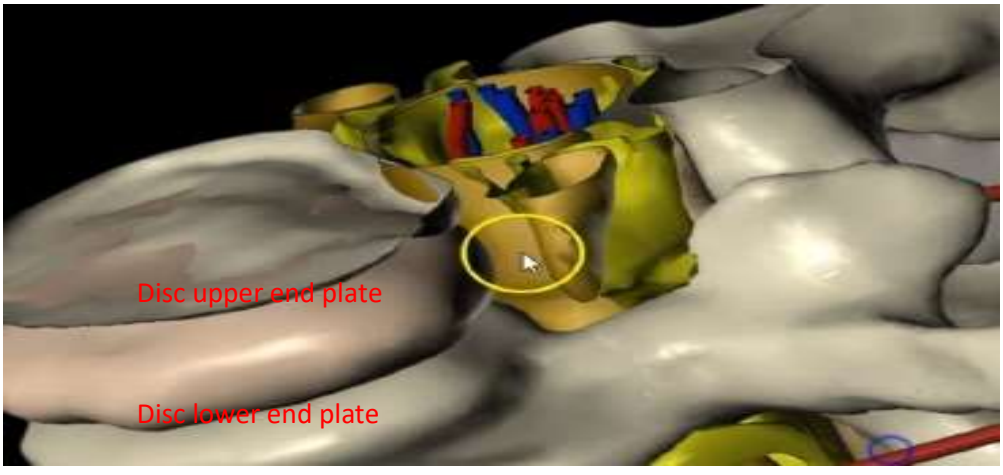
This is a sagittal disc level cut at middle zone shown by violet line in left A image,

B The coronal cut shows red pincer jaws, these are on both sides of interradicular part of the thecal sac

C The axial cut is showing ligamentum flavum that is marked in violet, over the posterolateral corners of the central canal, forming the jaws of the pincer. The section shows yellow is annulus that has lost its concavity. The disc bulge is seen in coronal cut too as marked by a blue arrow.

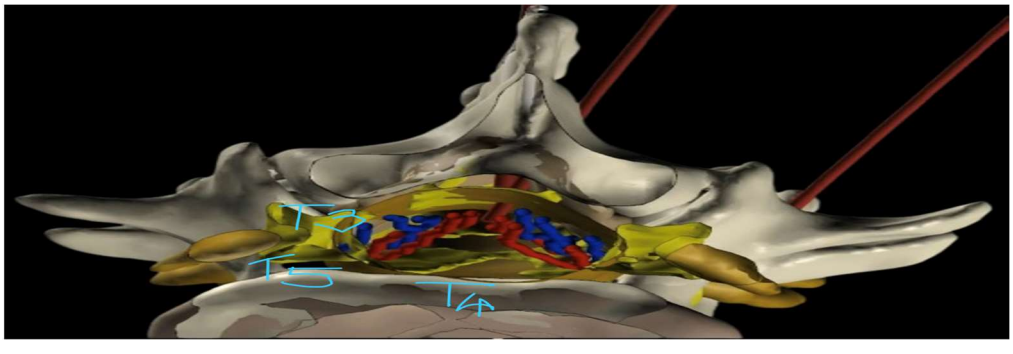
3 D model illustrations of our targets to highlight precision. Images are for middle zone at disc upper end plate left foraminal and canal area from above downwards towards lower zone.

Image 20/1 Axial cut at top of middle zone, endplate above. Cut is little oblique upwards towards back.



We see middle canal zone beginning at upper endplate [disc] . Exiting nerve has left. We see facet joints posterolateral. Sac shows roots spread more laterally.In this model disc margin is concave.

Image 20/2 Classic axial cut of middle canal zone caudal to image 20/1.



Central canal is edge to edge at facet. Post midline is much away from roots, traversing roots ready to leave. Target T3 medial facet face T4

disc T5 foraminal G knot related. All locations are reachable from foramen.

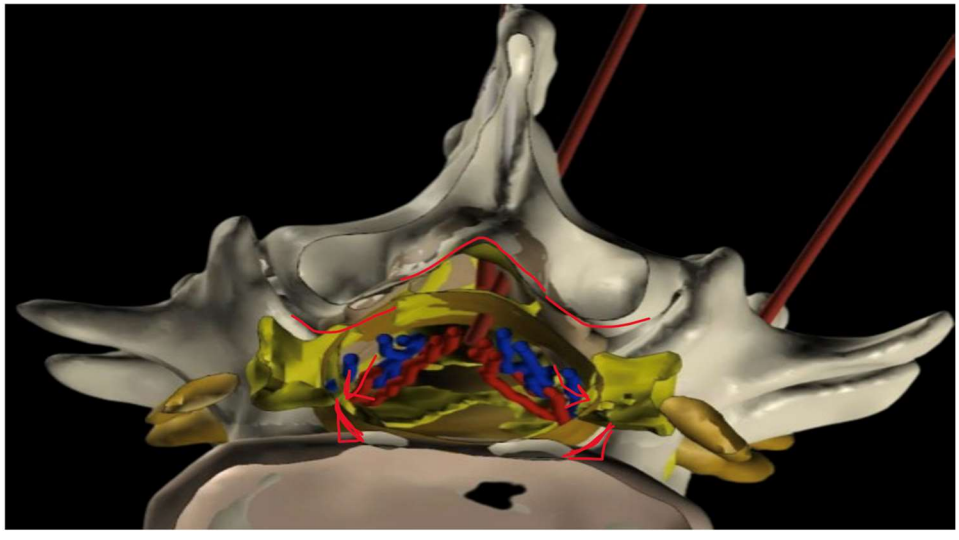
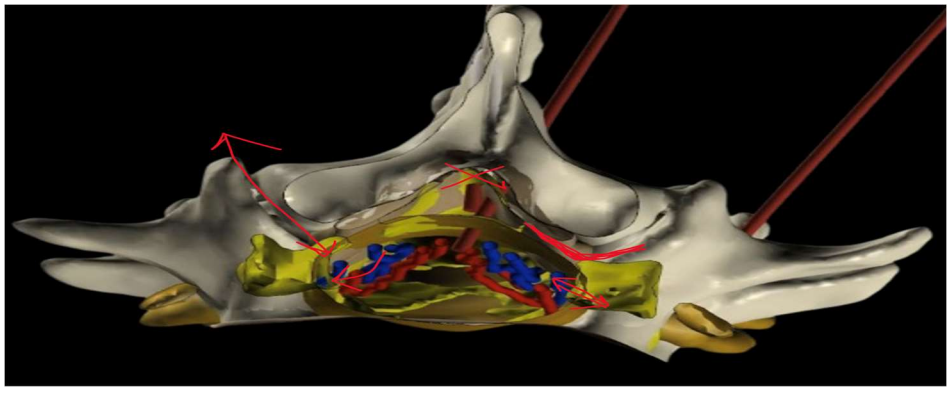


Image 20/3: Axila cut highlighting canal walls. Image 20/4: CANAL contents and walls axial cut more caudal to 20/3.

We see laminar edges, sub articular margins of facet, both side roots leaving sac. And corners of the sac ventrally. We see relation of interradicular intrathecal roots and facet edge. The double headed arrow is in facet joint. Cross is post midline. Arc is facet edge. Small arrow on left to show exiting root part 3 LR. Small hollow arrow inter radicular roots intrathecal. Bilateral foramen open without any neural tissue.



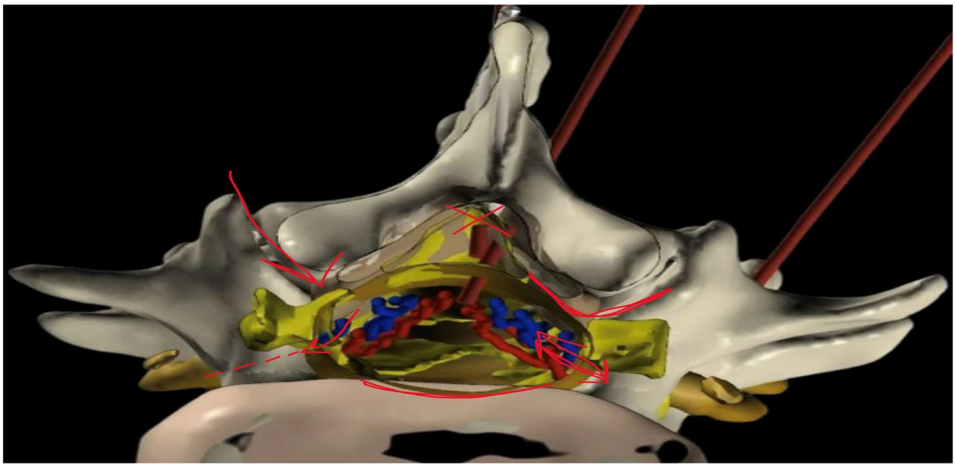
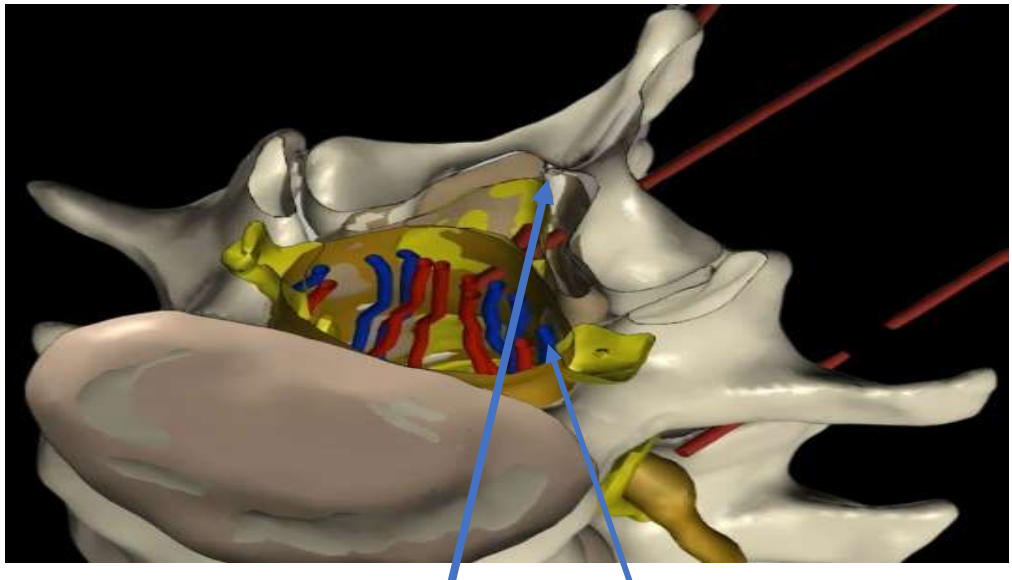

19

Image 20/5: Axial cut closer to lower disc endplate shows concave post annulus. Image 20/6 Axila cut at middle disc level canal zone

Ligamentum flavum seen on inner face of the facet joint. Traversing roots ready to leave sac. Red interupted line is roots under pedicle below.



Middle zone canal seen well, Lamina is away. Posterolateral facet edge IMP. WE SEE TRAVERSING ROOTS DISTRIBUTED MORE LATERALLY.

Image 20/7: Important "postero lateral" part of central canal wall causing stenosis. Our target T3.

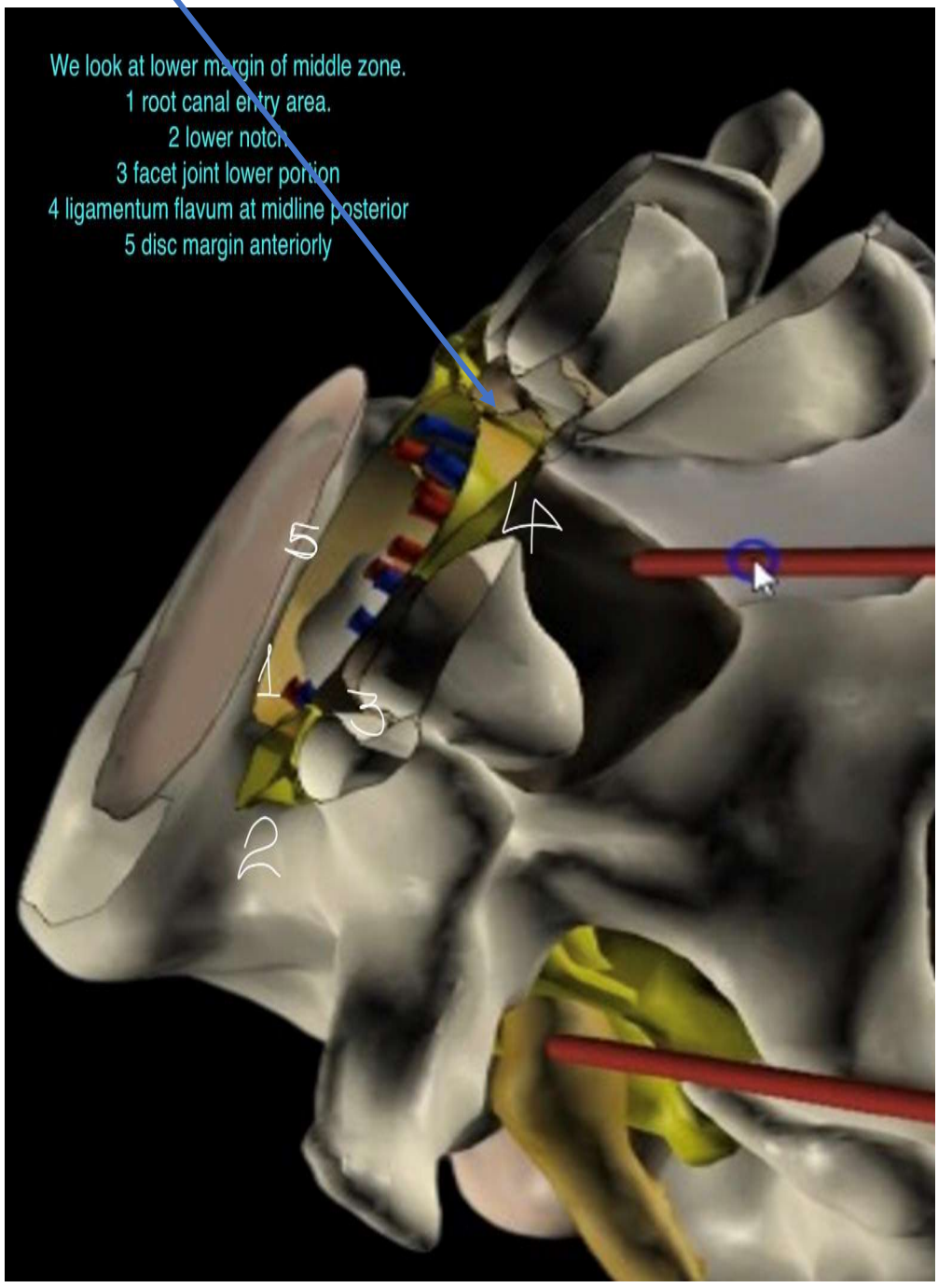
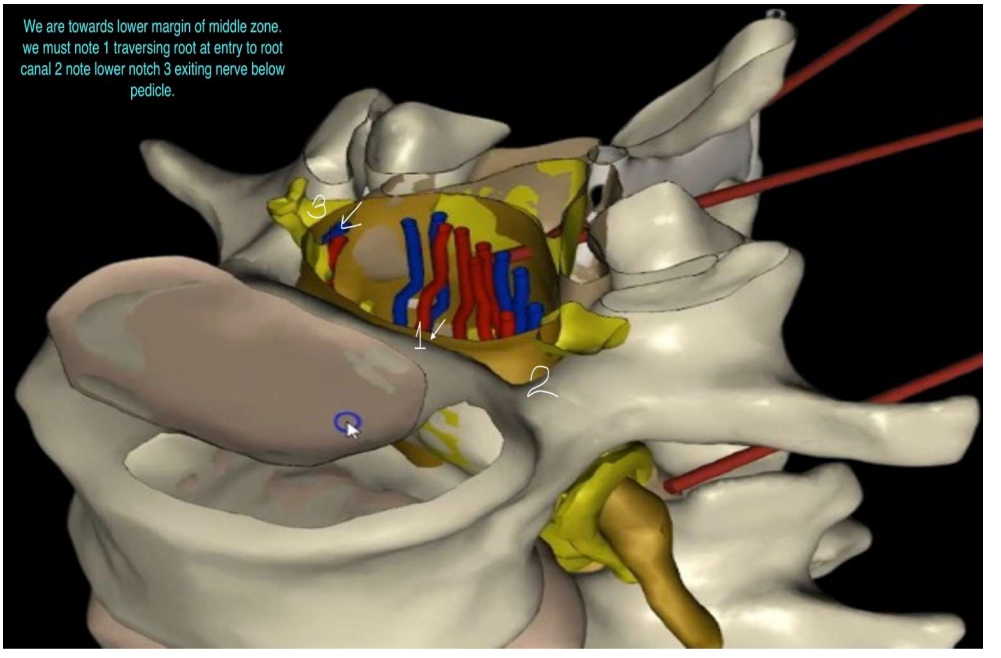


Image 20/8: Axial cut in lower foramen notch.



Lower endplate of disc approaching. That is lower limit of middle zone. Lower notch 2 above pedicle seen here. Note exiting root 3 and traversing root 1. AT ENTRY ZONE part 1.

Image 21 : Basic middle zone landing needle on disc.Under SAP.

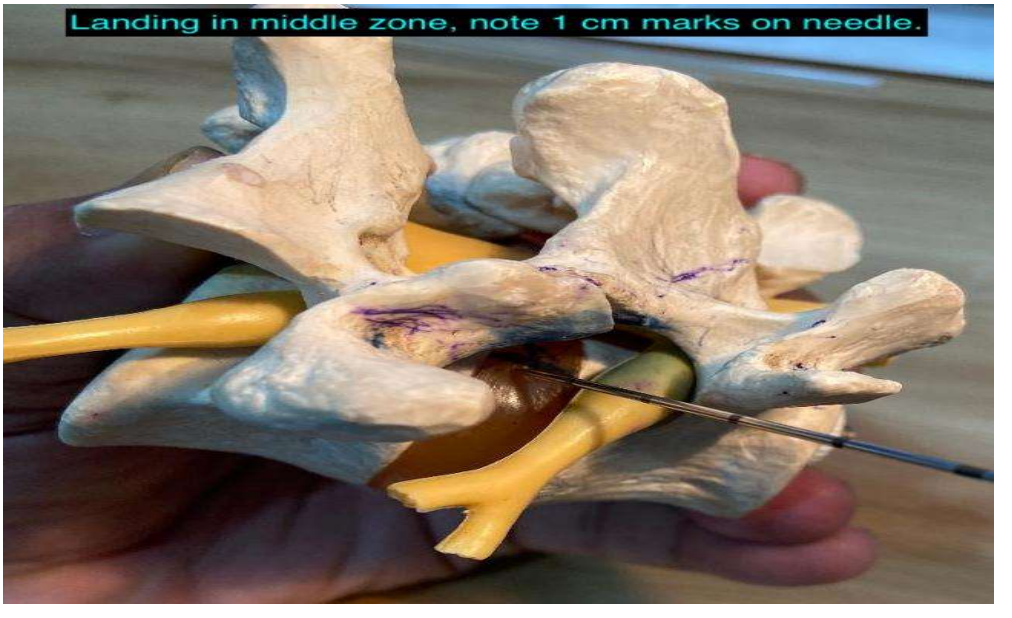
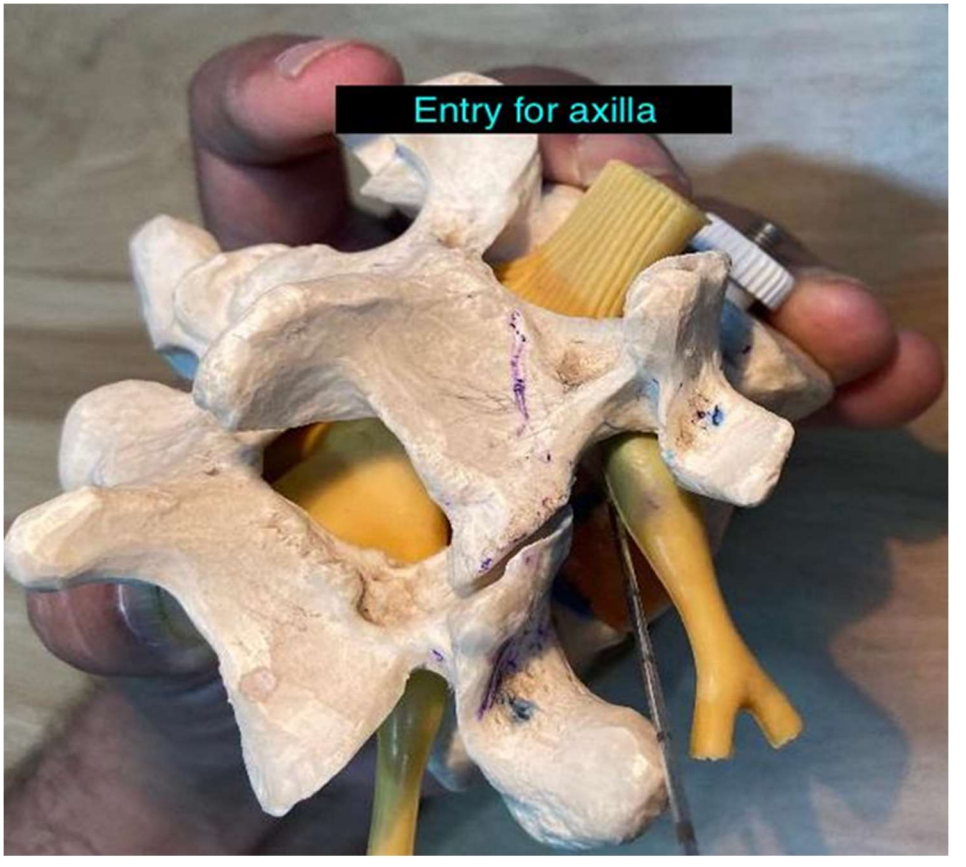


Image 22: Variation in landing for upper zone.

Image 23 Entry for upper zone axilla is close to end plate above.



For upper zone work we may remain anchored in mid zone but look towards axilla and work. WE may use extraforaminal anchor and teku to improve our mobility in foramen.

Image 24: Anchor in mid zone with upper zone work.

Image 25: Working under Sap can be achieved as image 27 or by coming from above. May be using natural teku of transverse process *where we go above it*.

N.B. Image intentionally shows needle below TP.

Images 26 Working on right SAP tip with left curette.

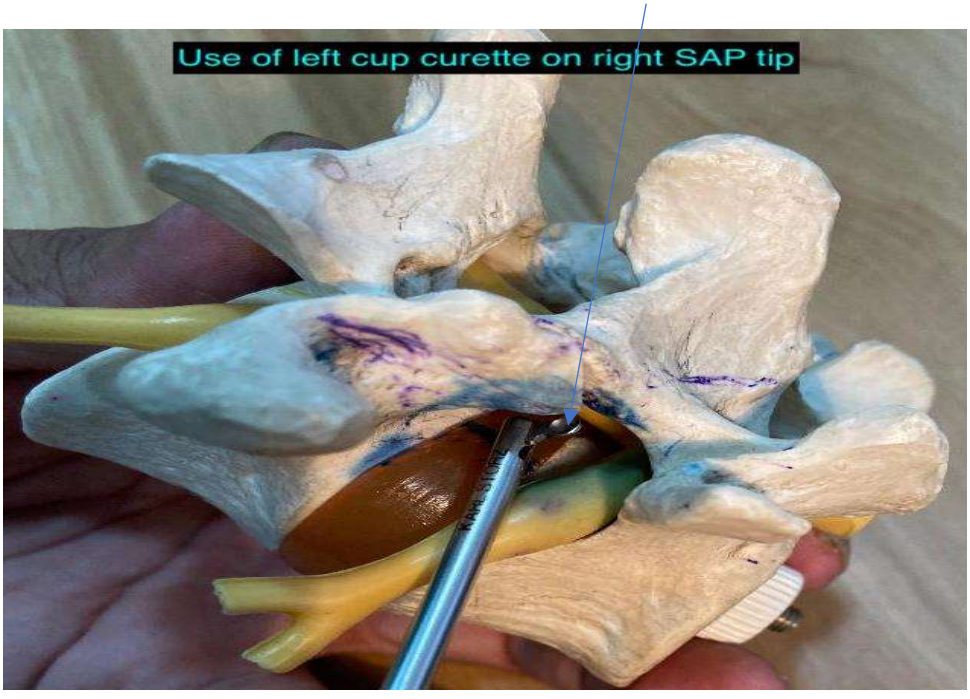
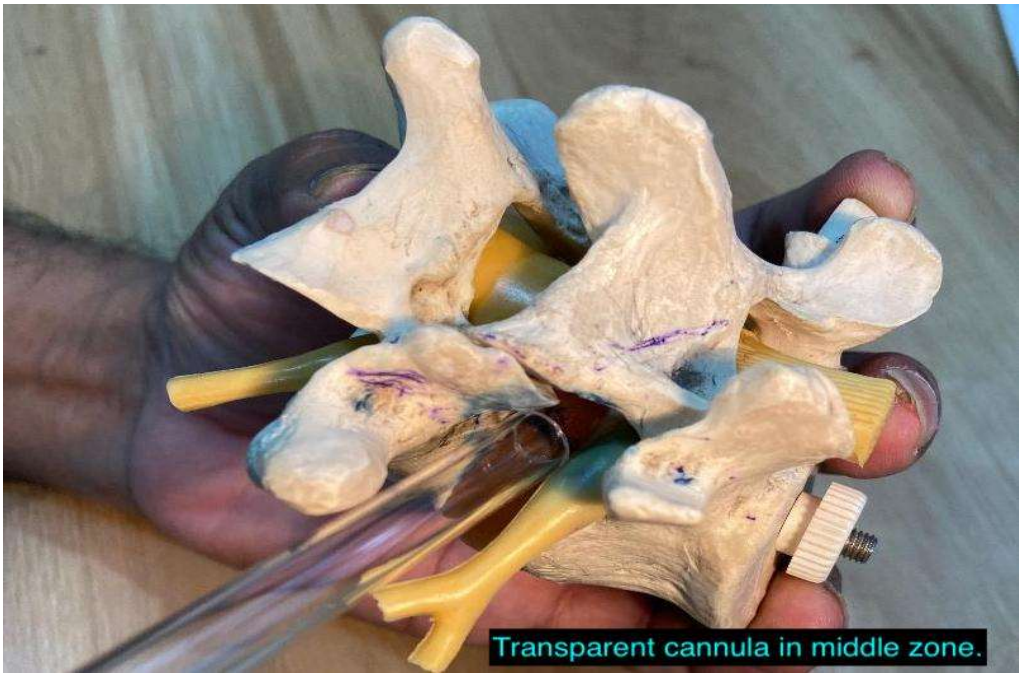


Image 27: Use of transparent working sheath or cannula in foramen. We see all surrounding soft tissue well, making our surgery safe.



Images 28 Entry for lower zone closer to lower endplate. Note we must be above TP of level above.

Image 29: Stay close to lower end plate for lower zone work.

When we extend our reach from middle to lower zone we land near lower end plate and in mid pedicle line closer to lower notch.

If we measure the height of foramen , the excursion of our instruments from pedicle above to below is not more than 20mm, but a proper trajectory is essential to reach target as we have a rigid scope. We may be facilitated by bendable and flexible instruments.

The fallacy of axial cuts in plane of disc must be appreciated. It makes us feel that V of lamina is important with its enclosed ligament in stenosis. This is far away from neural tissue and truth as well.

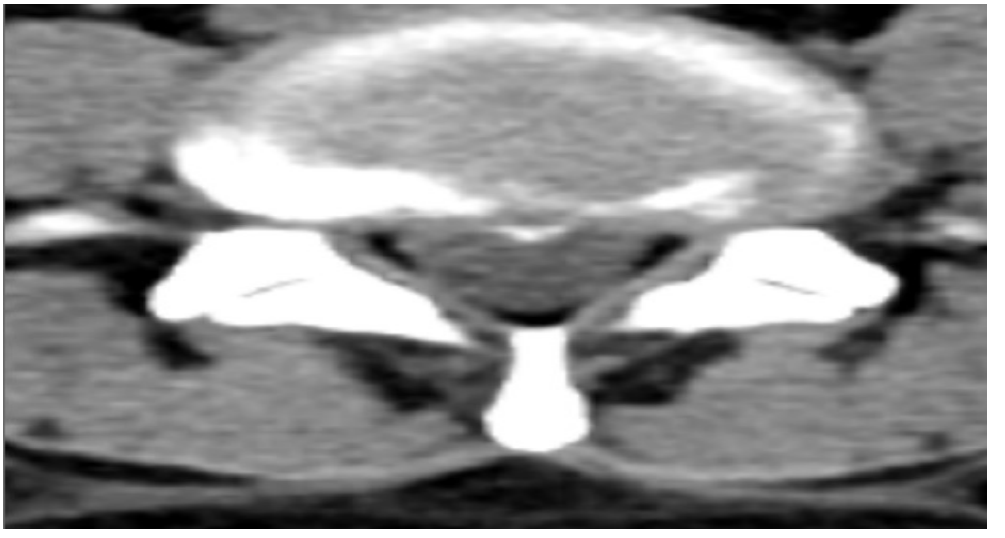
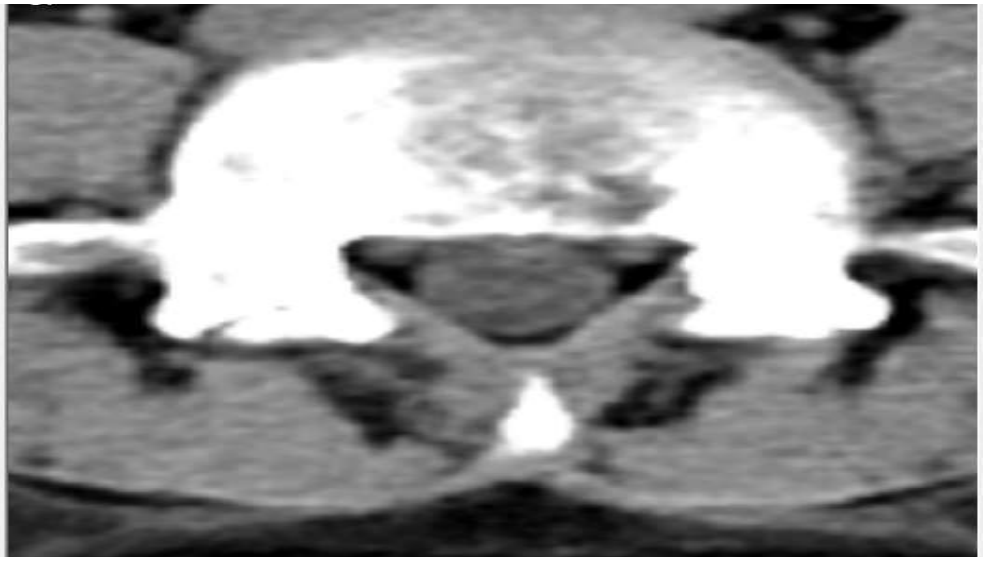


Image 30, 31: Interlaminar soft tissue at middle zone and lower border of middle zone.



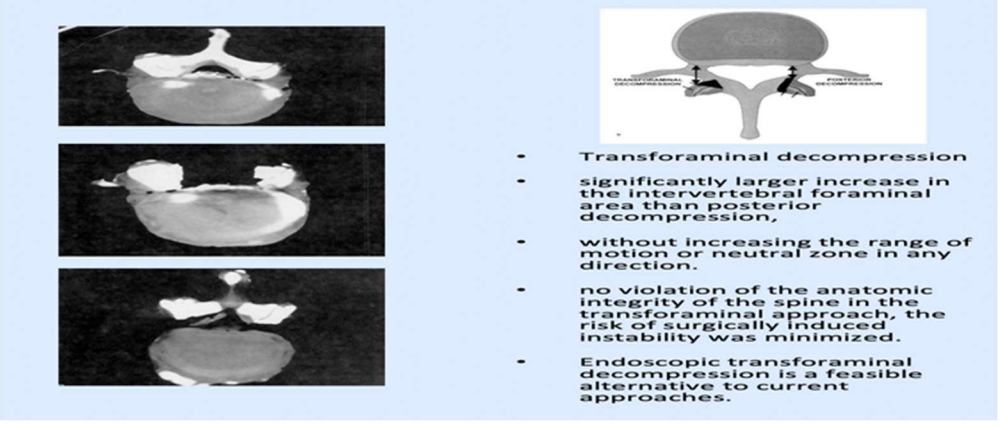
Images above clearly show the fallacy in CT images. The soft tissue in interlaminar window is not relevant to symptom generation. Only subarticular and medial facet face tissue is important.

SURGERY FOR MIDDLE ZONE steps:

Access to middle zone through foramen is well studied, validated and published. Middle zone access forms very basis of transforaminal surgery for disc herniations and now stenosis.

1. The entry point on skin and trajectory is changed as per our target, facet inclination and the likely texture of the target tissue. We land under facet.
2. Go over to tip of SAP cut it and then scrape the medial wall from SAP tip downwards and towards midline that covers the lateral ligament in upper zone.
3. The idea of reaching SAP inner surface or ligament is easy from above and around SAP tip. It is safer too.
4. We land at medial pedicle line or lateral edge of dural sac in FLOOR. Entry and lateral decompression is by bony "foraminoplasty" by undercutting ventral facet till we come at edge of the dural sac then by Channelplasty.
5. We work more ON INNER SURFACE OF FACET.
6. Subarticular part of the ligamentum that lies directly under the facet joint is removed. The additional undercutting of ventral facet till free root or lateral thecal sac is seen; contributes to central canal decompression adequately.
7. The axilla is more dorsal as roots are relatively fixed there. If both root canal entry part 1 in lower foramen and part 3 + uz exit areas in upper foramen are immobilised then inter radicular position in mid foramen may get more affected by posterolateral soft tissue hypertrophy and on SAP tip as jaws of PINCER.

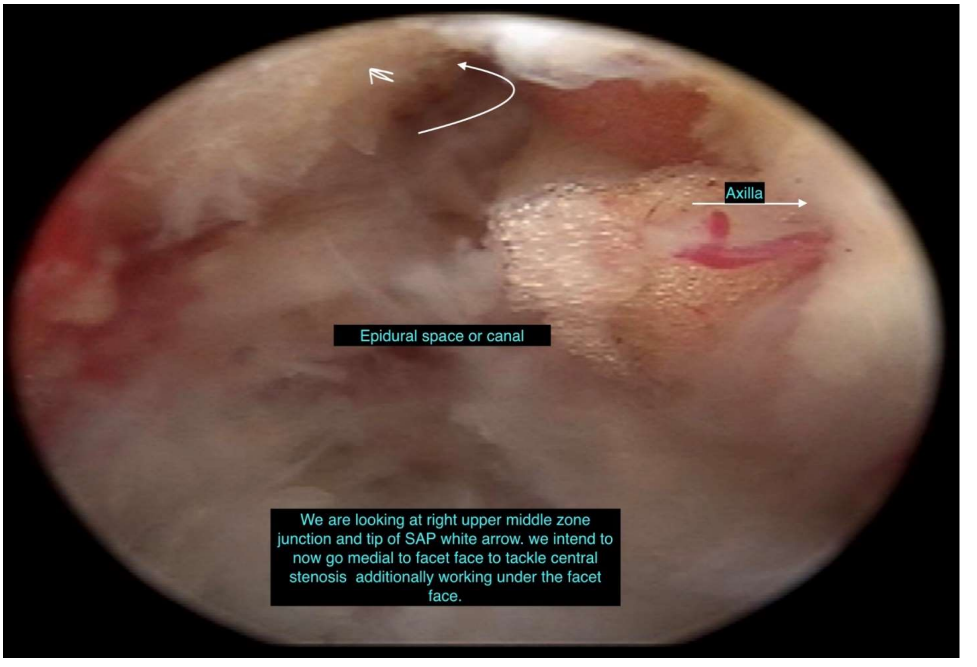
8. Medial faces of facets bind CENTRAL canal on sides in sublaminar and subarticular part. The nerve fibres cannot move in case of compression by disc or bone.
9. If it is only unilateral, it is less irritating for traversing nerve root because it has more space to move intrathecally. It is buffered by CSF around and compressible venous plexus and epidural fat. Severe stretching and compression of the "inter radicular" part of traversing nerve may result in symptoms specially if compressed bilaterally in central stenosis.
10. MRI sometimes shows G knot less prominent than actual during in vivo visualization.
11. Middle zone CENTRAL CANAL stenosis can be easily relieved by lowering hard discal floor and raising nonarticular bony facet and soft tissue roof of the canal restoring the volume of the canal. If need be bilaterally.
12. Image 32: Osman and Punjabi cadaver studies of transforaminal bony decompression in stenosis Vis a Vis posterior midline access and laminotomy or laminectomy: It shows transforaminal ventral facet decompression gives larger volume expansion and interlaminar is biomechanically inherently destabilizing. [Study of 1997].

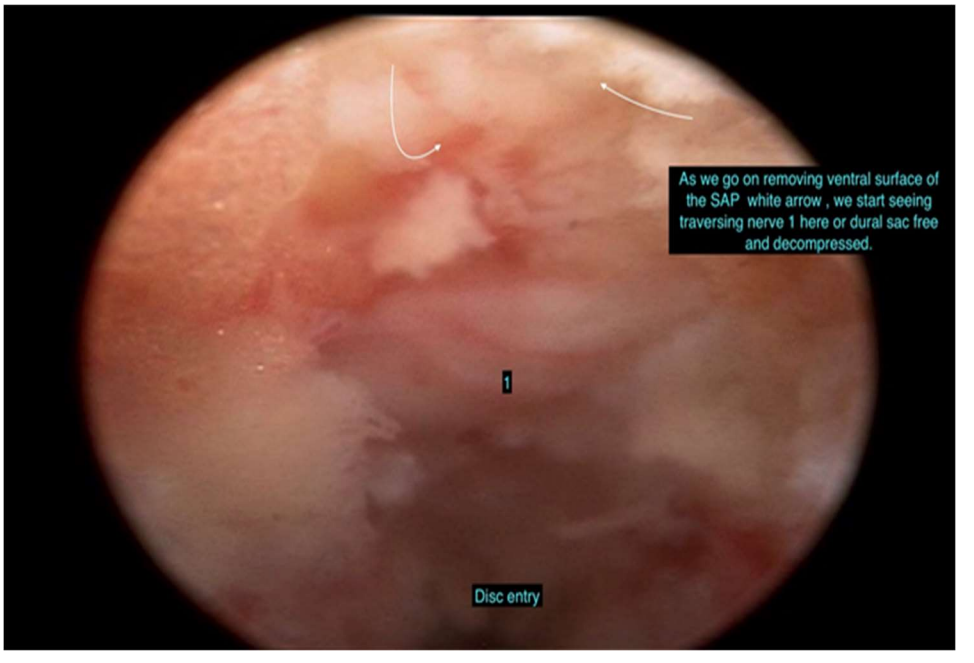


Illustrative cases: 1

Image 33, 34: Strategy for middle to upper to middle zone work.

We land in middle zone then after working in upper zone we turn over and inside SAP then middle under facet.





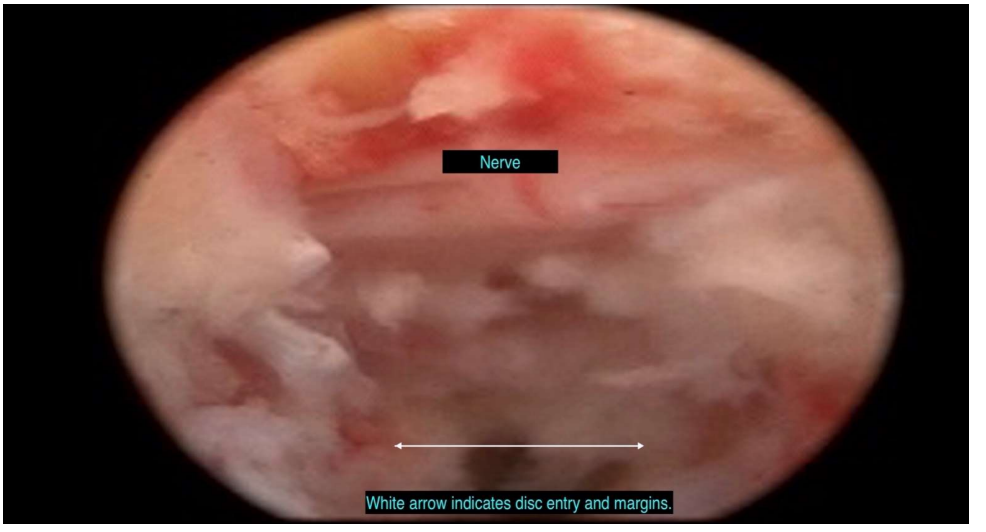
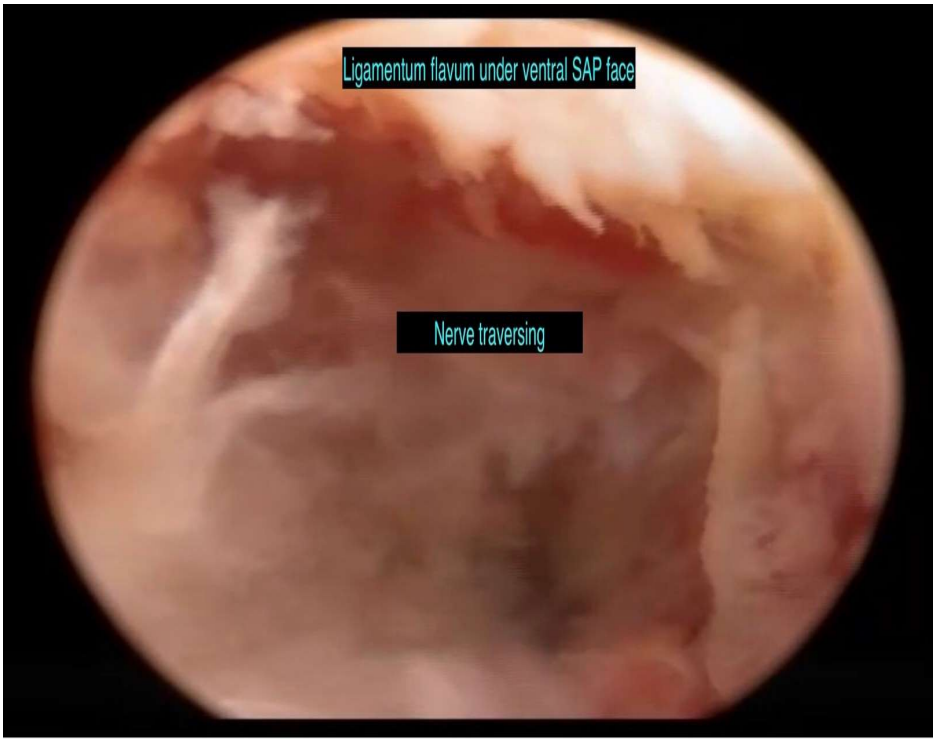


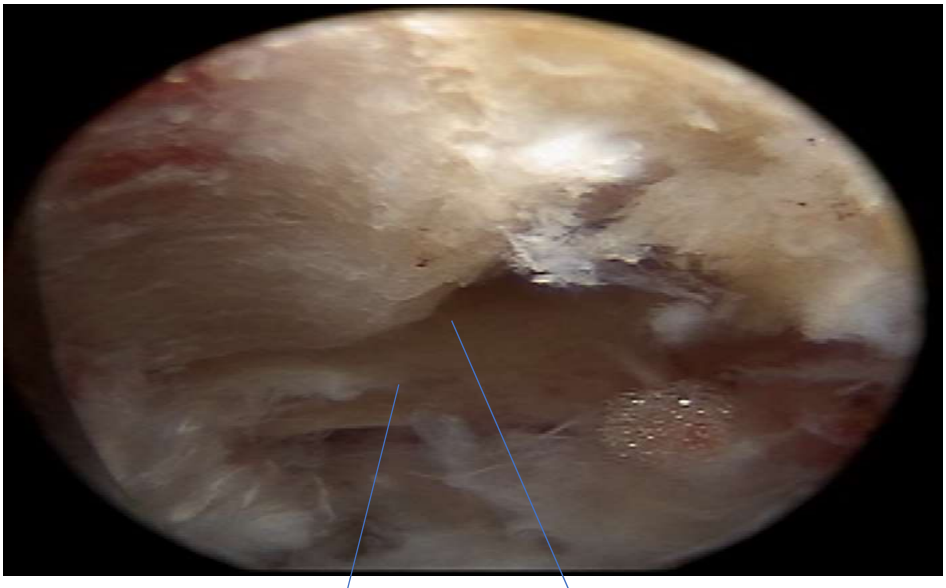
IMAGE35 Anterior Middle zone disc work lowering floor of the canal. Image 36: cause in middle zone is anterior in disc annulus T4



We lower the floor working on posterior annulus. In middle zone we target T3 medial facet face, T4 Disc posterior annulus and T5 g knot in foramen.

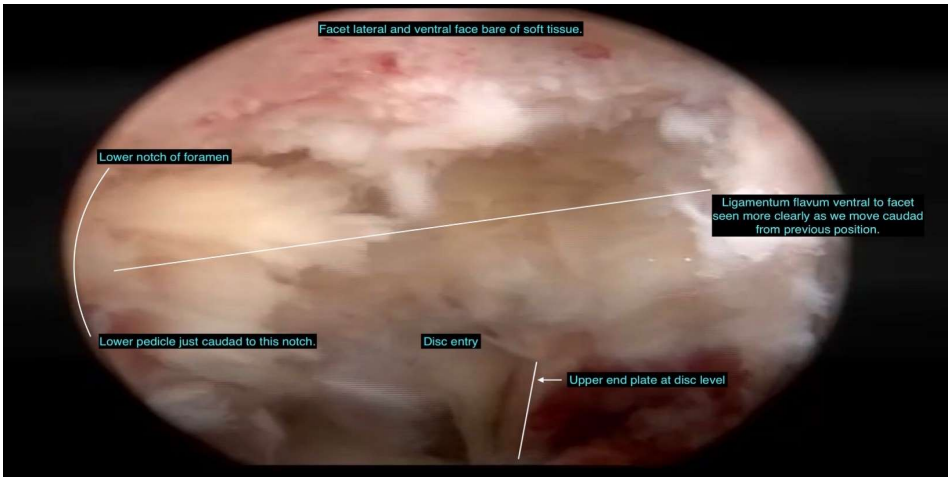
Illustrative CASE 2 Right side access.

Image 37: SAP right side seen above once we retreat in foramen.



We are in middle zone and retreating in foramen, we see sap tip, here it is cut. So we see more lateral ventral SAP. Plane between facet and ligamentum and epidural plane is seen clearly.

Image 38: Cause posterior T3, plan is raising roof and beyond.



Facet is progressively drilled/ burred under vision to go right up to edge of facet for epidural plane. We stay on lateral facet face and then turn our cannula towards leg as seen below. This is done under vision.

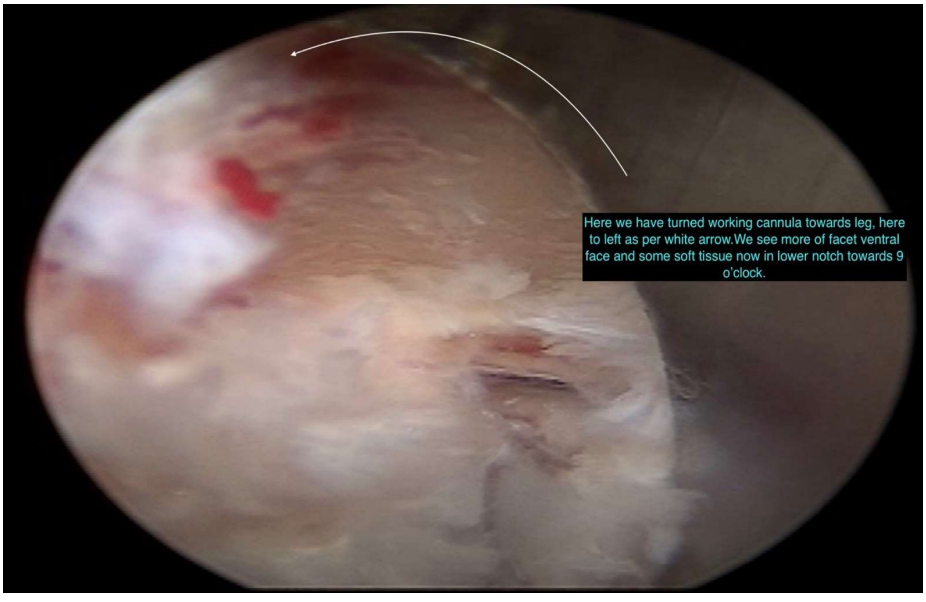
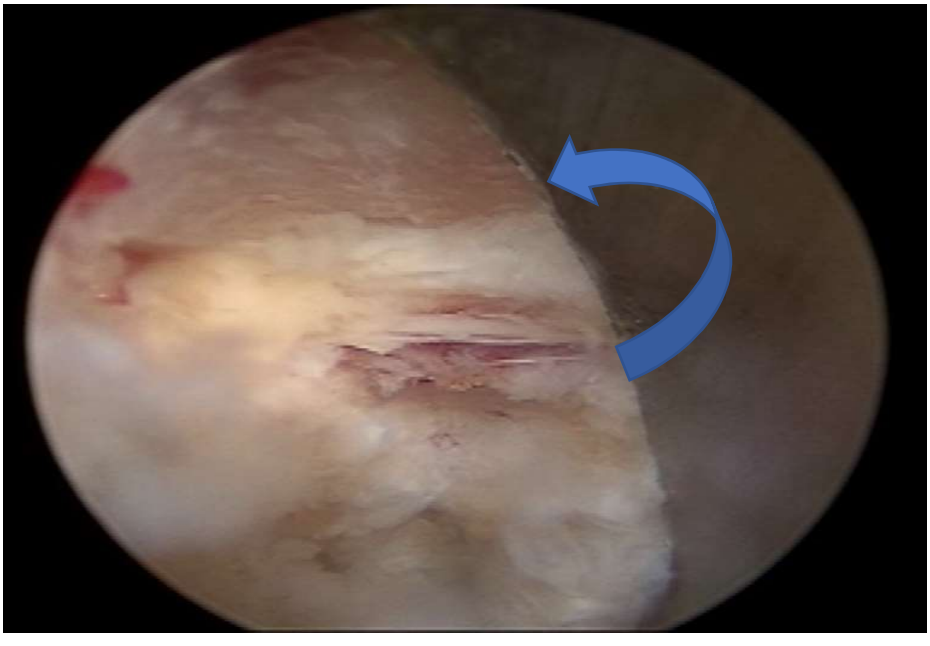


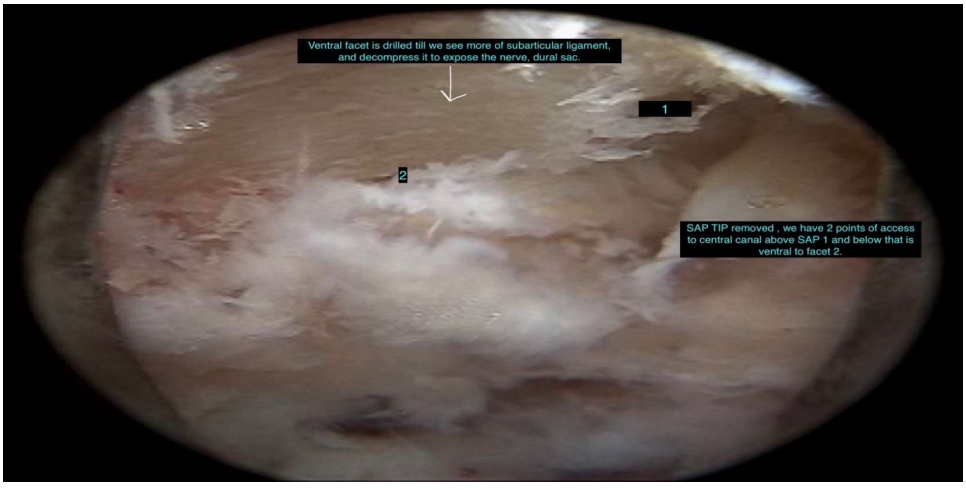
Image 39: Under SAP drill burr ventral facet, the turn downwards

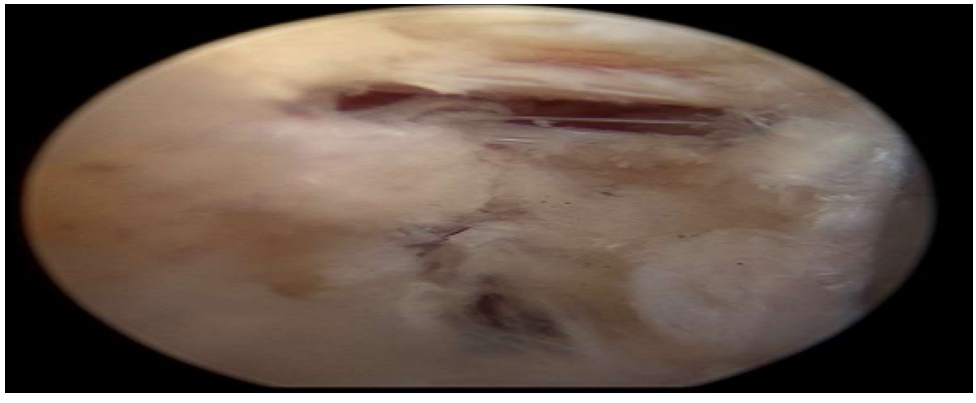
Image 40: Turned further down towards 10 oclock.

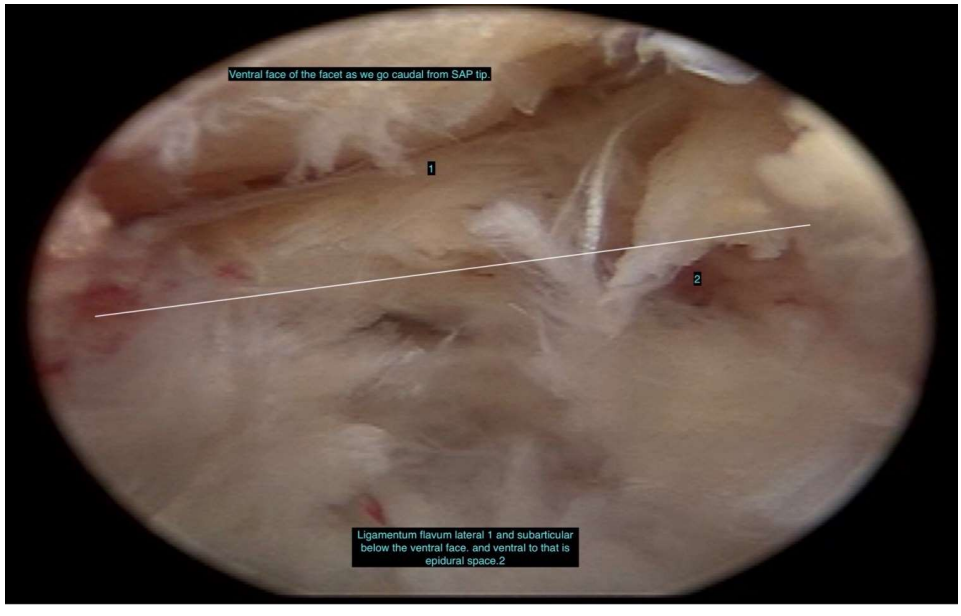


We see lateral ventral facet edge. We cut more of ventral facet, till we see traversing root or free thecal sac. See intra canal structures, ligamentum flavum.Distinction from case 1 before is then it was lowering of floor , here we are raising roof of the canal. Work towards 12, 11,10 o'clock.

Images: 41, 42, 43 Work along lateral facet face and under it.Towards 9 o'clock or lower notch and traversing root entering part 1 root canal.

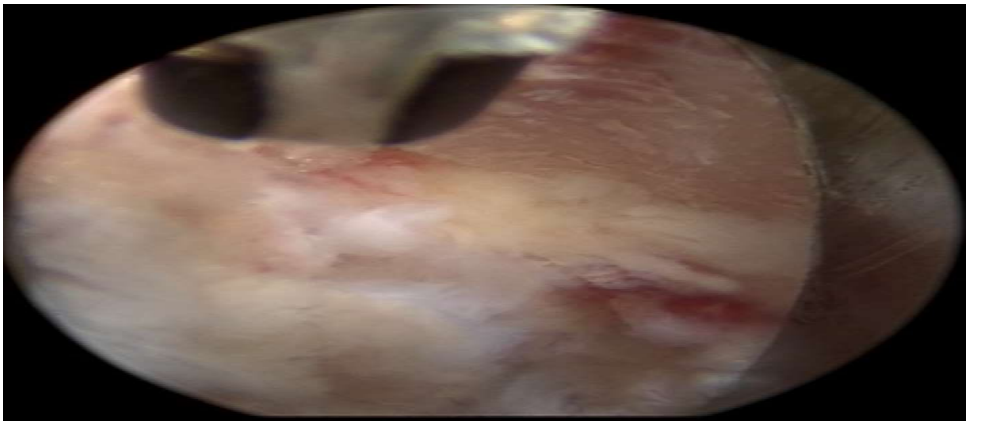




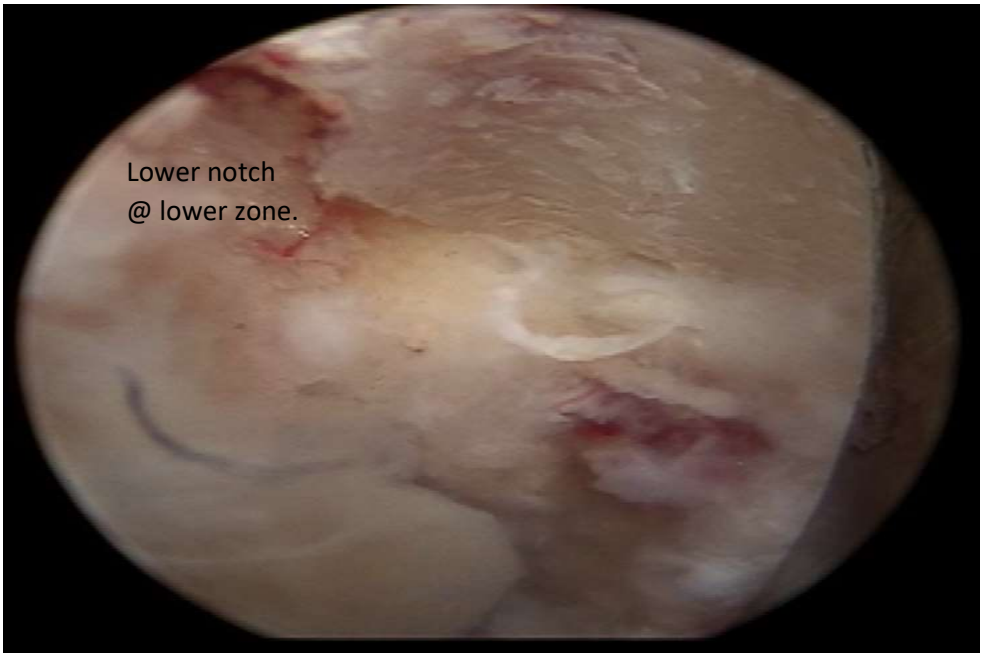


Tissue in lower notch and along lower endplate seen. On clearing epidural tissue plane clear. Hard osteophytic tissue at lower endplate seen. As we go caudad we start getting more epidural ooz.

Image 44,45. Use of bipolar cautery towards lower notch.



Using a bipolar over lower notch and veins. Oozing here can be low pressure venous copious and constant. Please guard against accidently touching traversing nerve here at entry to root canal. Lower zone is covered with fat at 9 .



Once this tissue in lower notch and under facet epidural edge start moving together with water column movement our decompressiuon is nearing end. We can also see lower edge of the facet near notch.

Image 46 Traversing nerve/dural sac seen freely decompressed.

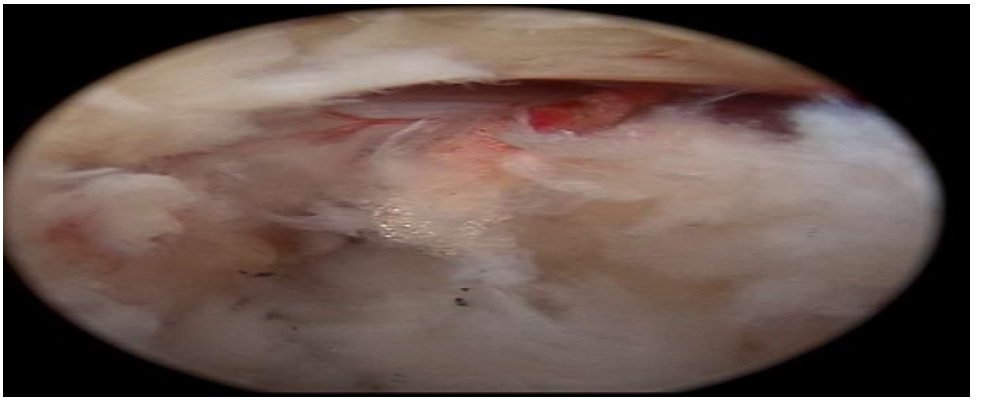
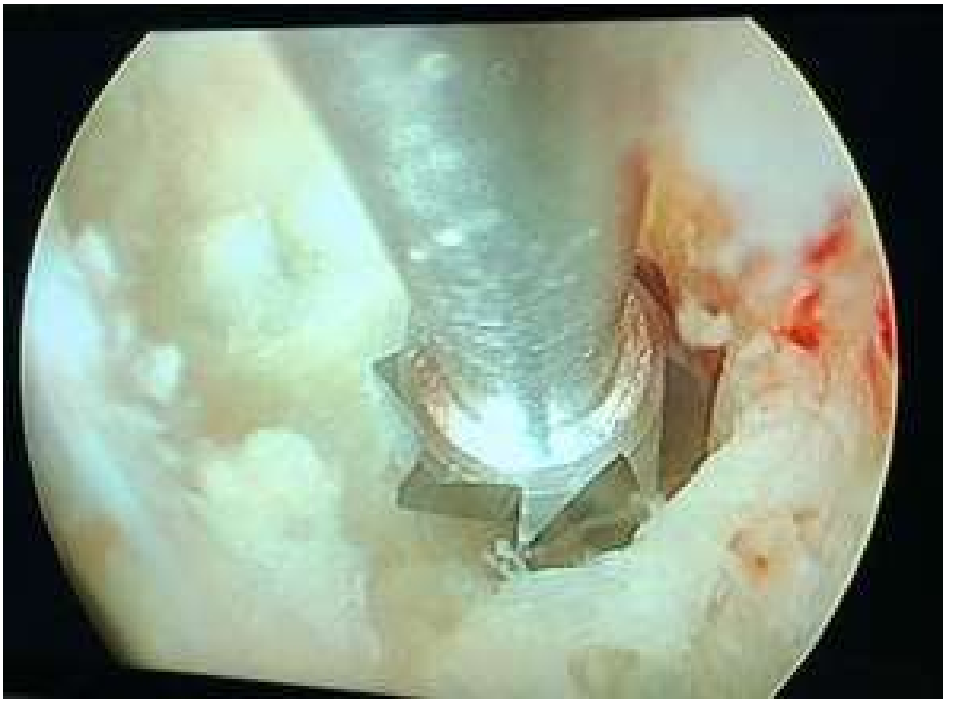


Image 47: burr working on facet.

Use of burr slow speed 525 RPM on soft and hard tissue in roof and lateral facet wall and facet edge.



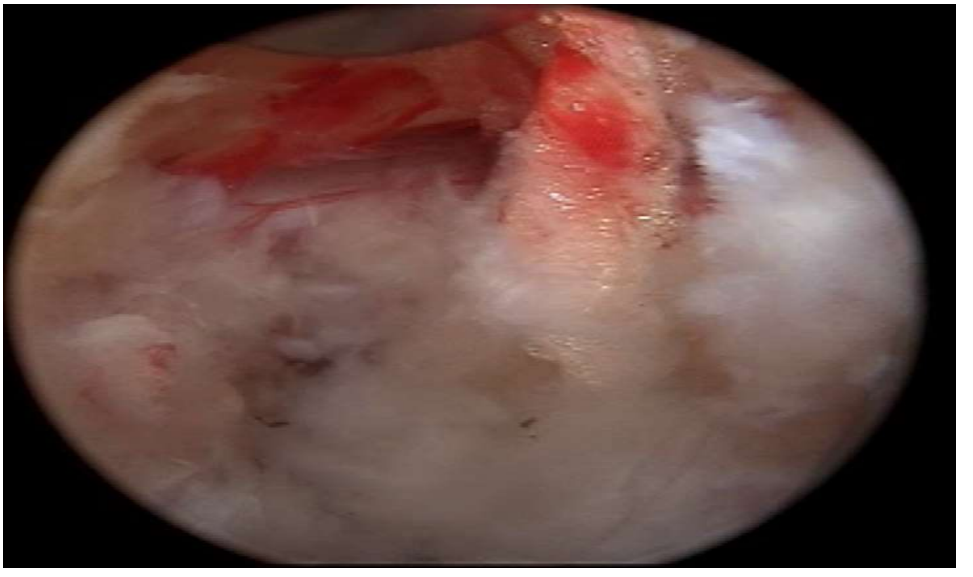
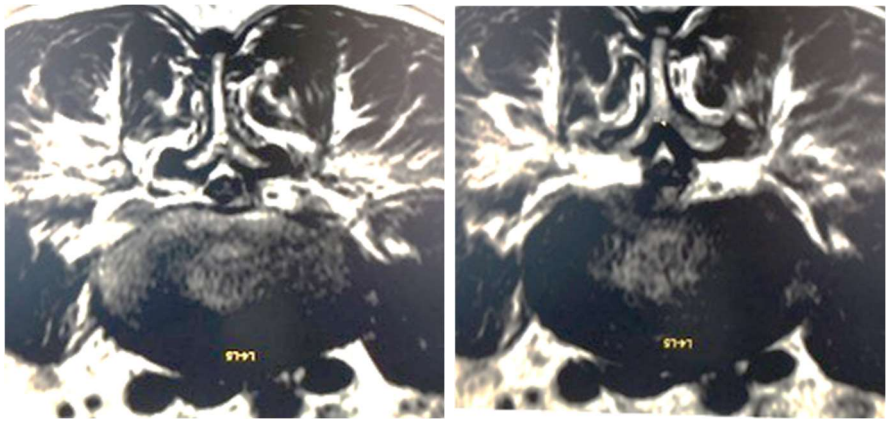


Image 48: RAISING roof leads to central canal. Image 49: Burr working under and on ventral facet. Tip at facet edge.

Decompressed thecal sac and central canal. Traversing root in lower zone entry to root canal. Ligamentum flavum is contiguous from upper sub pars to middle [medial facet plane] to lower zone lateral recess roof part 2.

Illustrative CASE 3:

Images 50 A B ventral facet pre under cutting op. and post op.



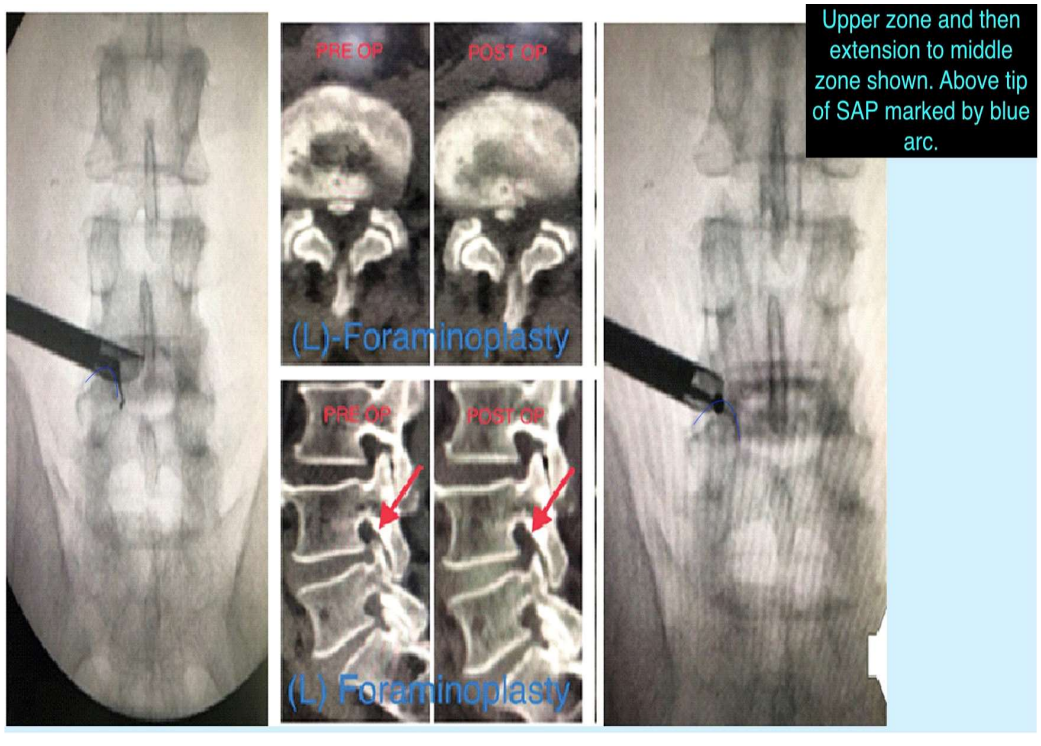
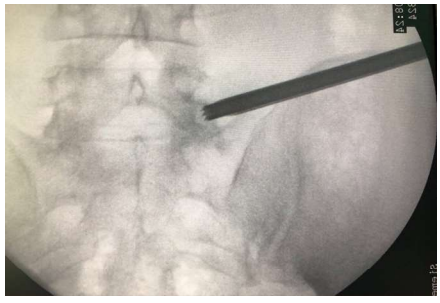
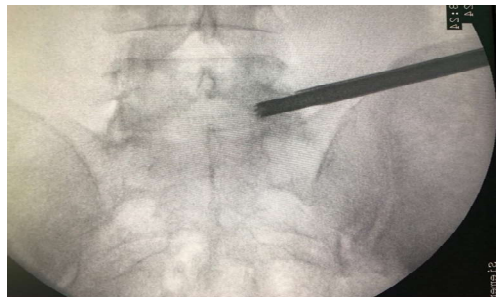
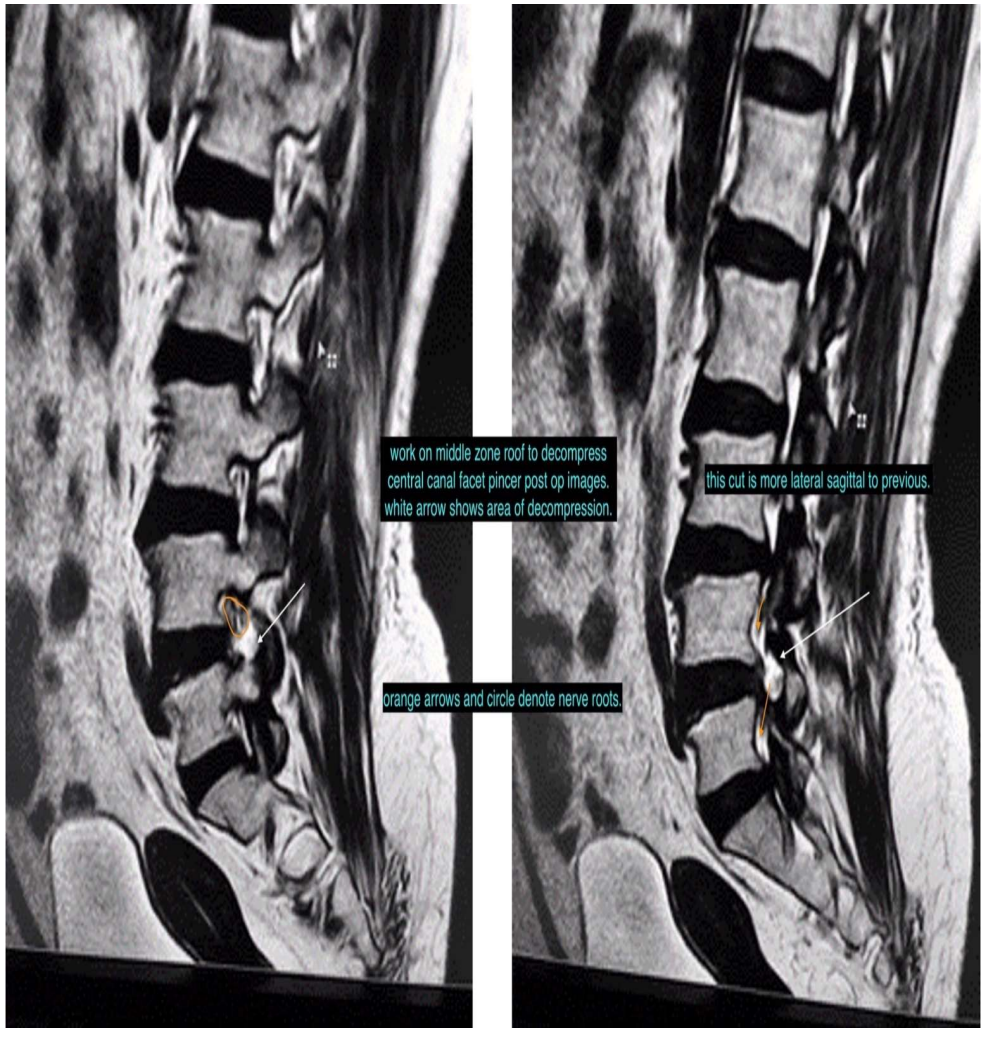


Image 51, 52 B, 53 AB Upper zone decompression is basically clearing of axilla and decompressing exiting nerve. Use of hook for confirmation seen in lower left image for lower zone confirmation.

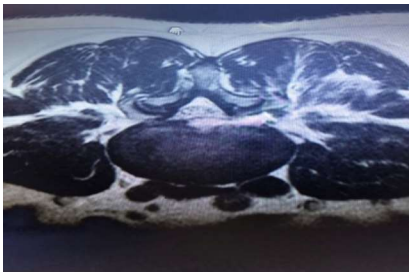




Images 53 A B: Use of trephines on facet tips and facet ventral surface. Image 51, 52: Sag post op images show facet undercut.



Images 54 A B postoperative axial cuts showing raising roof in central canal stenosis. MRI and CT images.



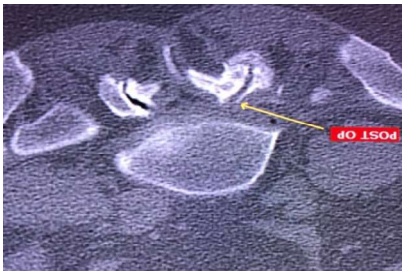
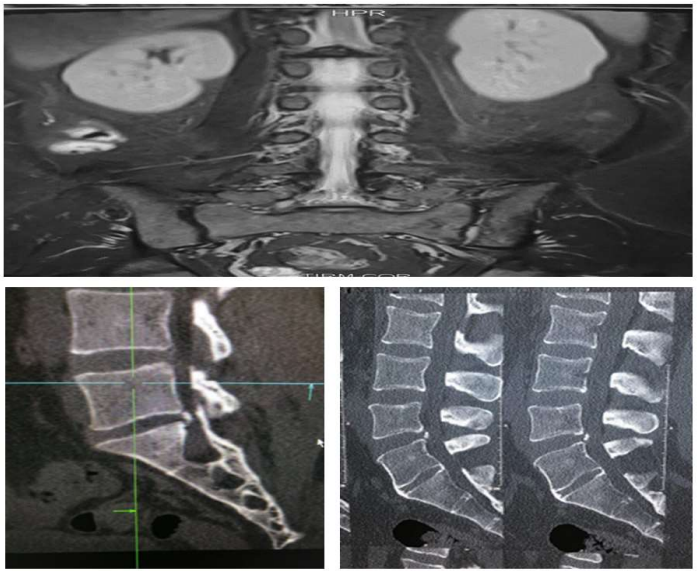
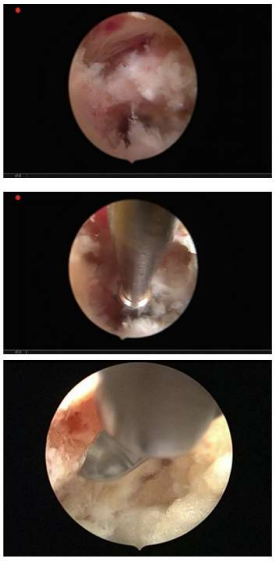


Image 55 A B shows a left side undercut non-articular ventral facet for mid zone decompression. Rt. we see ventral facet undercut up to facet edge for central canal decompression in CT.

More clarity of this is shown by Osman and Punjabi's work of transforaminal decompression Vis a Vis post midline interlaminar. [Cadaver studies 1997. Above is live surgical image].

Image 55. Use of curette and burr intradiscal on osteophyte for ventral middle zone floor work.

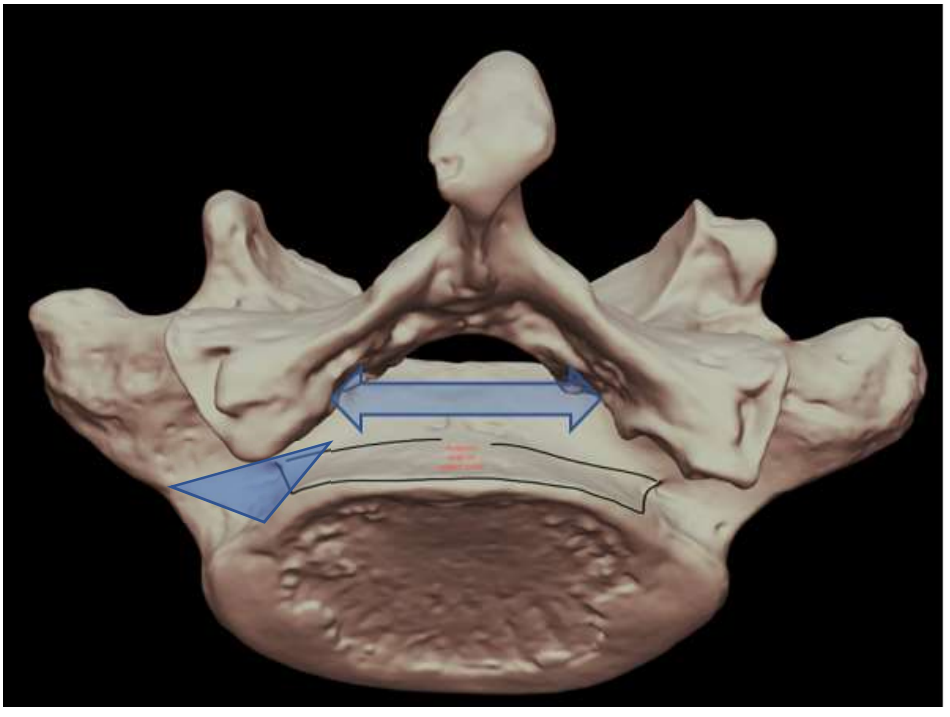




Coronal MRI and Sag Ct cuts show the L5S1 osteophytes, could be calcified ossified annulus in some cases. Rt 3 images show end plate osteophyte removed by use of burr or curette, intra discal, under LA.

4 Extending reach to Upper zone: Targets T0, T1, T2

Image 1. Upper zone seen below pedicle, between facet edges.



UPPER Zone is canal is lower part of parapedicular hidden zone of Macnab. It is continuation of part 3 buffer zone above and also known as exit zone for root canal. It is between lower endplate and lower pedicle border. It is farthest from interlaminar entry. It is upper laterally open foramen. Roof is facet edge to other side facet edge shown by blue arrow and is wider than interpedicular area [marked black]. Pale blue triangle is our view of upper zone roof. Apex of triangle is our landing point close to end plate and we look up.

In traditional surgery only with wide facetectomy and laminectomy from behind we may be able to reach symptom causing area or our targets lateral to facet edge. Upper zone gives exiting 1 root stenosis.

The access to upper zone is easy as we land close to end plate of disc [shown above as triangle base] and cross over above Sap. Going inside canal is easy and there is no BONY border or edge of facet to cross. This houses all causes T1 of the failed open surgery. Failure is due to inability of inter laminar central entry to cross facet edge and access this lateral part of canal. Transforaminal entry and access has the inherent ability to work in upper zone. Anatomical fact remains that transforaminal entry alone can reach this zone easily under local anaesthesia. Since we are working around DRG having patient awake and aware is a significant change in surgical strategy.

Since ligamentum flavum is contiguous; our entry and access to central canal is easy above SAP TIP. We are initially able to work on SAP tip and then additionally ventral facet undercutting adds to our ability in accessing central canal at pincer jaws. Pincer jaws and tip of the pincer are thus both accessible in one entry.

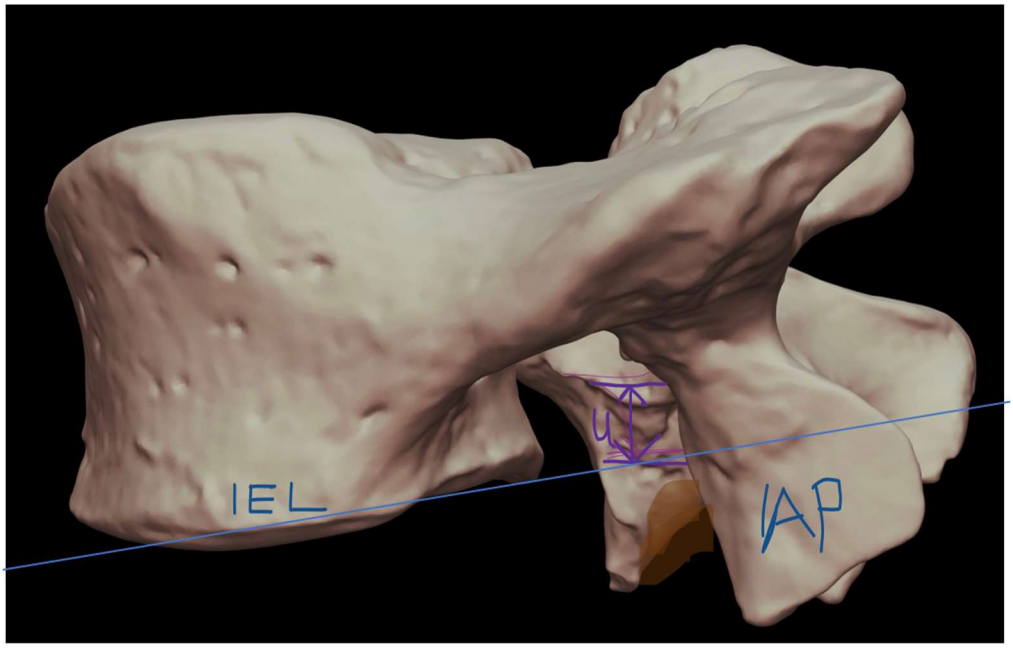
We are able to cover most significant part of canal stenosis affecting free extrathecal exiting root and the intrathecal early part of sac with traversing roots floating in CSF padded by fat but affected by ligamentum flavum on tip of SAP and inner facet face.

VARIABLE Location of DRG and axilla must be assessed pre-op in images. Indirect imaging of upper zone can be done by radiculogram and epidurogram. There is no facet joint in upper zone T0. The axilla is between exiting nerve and intrathecal traversing root MEDIAL to FACET EDGE. Lateral ligamentum flavum in roof of this zone is unknown to traditional surgeons. Newer 3D fusion image based understanding of lateral ligamentum flavum makes surgery very valuable.

Bony Rings and contents: The upper zone starts from lower border of vertebra and extends up to lower border pedicle of that vertebra. Bony dimensions here do not change after skeletal maturity. Body is anterior wall of the UPPER zone. Violet line marks bony roof of upper zone. IAP articular surface and upper attachment of ligamentum [brown] on LAMINA is below blue line.

The anterior wall is covered by PLL. Close to middle of body is nutrient artery. The pars interarticularis forms roof of this zone laterally and healing fibrocartilage in cases of lysis can affect the root and DRG. The defect at lysis Target 2 may become symptomatic. The lateral wall of the upper zone canal is open "upper larger part of the foramen". There are no lateral recesses at this level, the foramina contain dorsal root ganglion. The segmental artery and branches lie ventral AND LATERAL to the DRG close to lower border of the pedicle.

Image 2 side and back view of the upper zone in bone model.



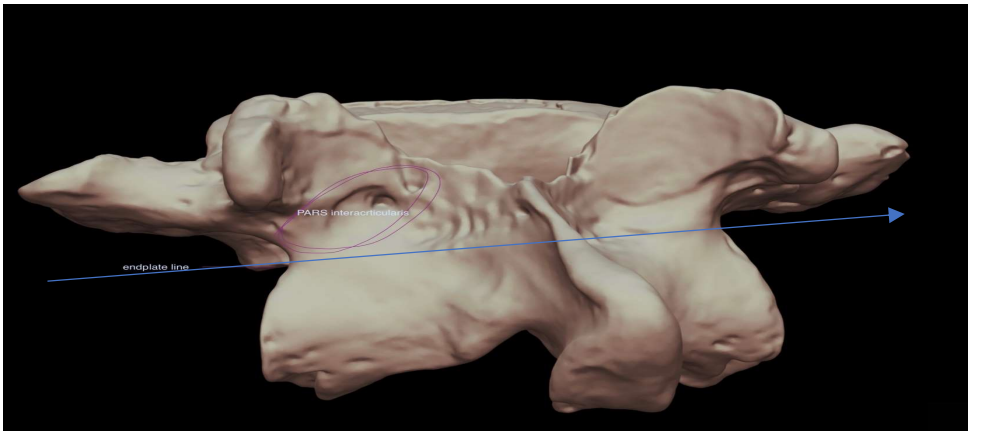
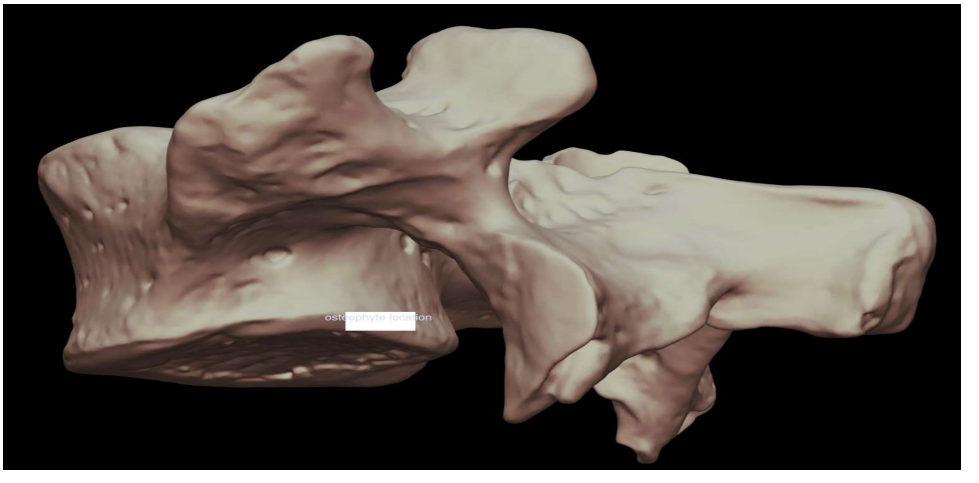


Image 3 4: pars marked and common location marked for paracentral osteophytes.



Zone is covered posterolaterally by lamina but dorsally lamina slopes down and away. THERE IS NO LIGT ABOVE IEL RIDGE [blue line above]. Facet joint is entirely below level of the upper zone, best seen in sagittal view. When we approach upper zone through foramen; axilla is fairly dorsal above SAP tip and SAP soft tissue cap. The DRG and roots are surrounded by peridural membrane that is known to have synovium like characteristics. Accompanying segmental artery gives transmitted pulsations to the DRG. The dural sac at this level usually has a rounded aspect. There is NO facet edge to cross, so central canal entry and working is easy.

There are no root sleeves to be seen here except sometimes at L5-S1. Veins from segment draining out the axilla and related tissue come out to join ascending lumbar vein they may be included in peridural membrane. There is abundant epidural fat in younger and healthy patients. The retrodural fat pad here is not as deep as at the disc level. There is abundant fat ventrolateral to the dural sac extending laterally into the intervertebral foramen and surrounding the dorsal root ganglion.

Image 5 Schema of thecal sac and its interradicular part.

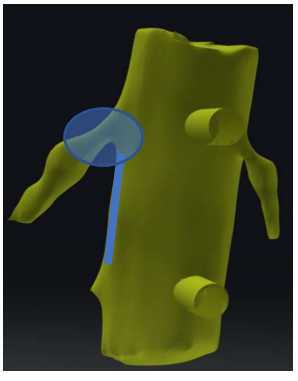


Image of thecal sac from 3 d model. Upper zone we deal with axilla Blue circle UZ, exiting root and upper part of interradicular [IR] [blue line] part of thecal sac. Middle zone deals with IR part. Upper and lower zones deal with extrathecal part of roots. Central canal from facet edge to edge is related to IR thecal sac.

The target T1 tissue is towards roof of upper zone. This may be lateral ligamentum flavum and all hypertrophied tissue in axilla of the exiting root and thecal sac. Lack of awareness, inability to visualize and inability to reach and remove this tissue is commonest cause of failed open surgery. MRI may not show the true extent of this soft tissue, this may also form part of g knot [T5] in foramen. If disc is collapsing tip of SAP may over ride into this zone. Superior foraminal ligament AND FACET CAPSULE may be important wrt axilla. Axilla level may vary. T2 is bony pars defect getting repaired with fibro cartilage that may grow ventrally in upper zone and then cause symptoms. T0 is just to remind us that there is no disc and facet joint in upper zone.

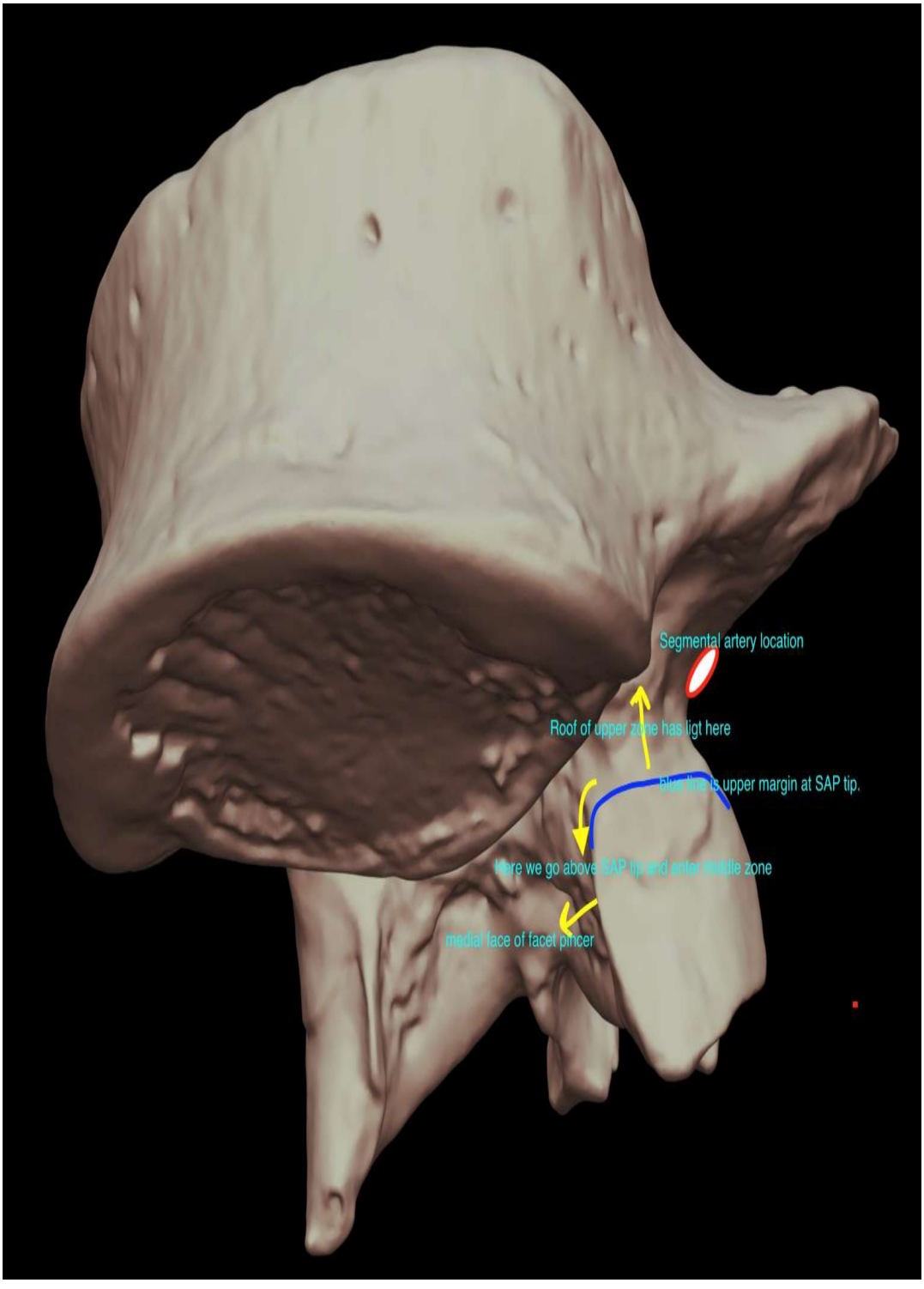
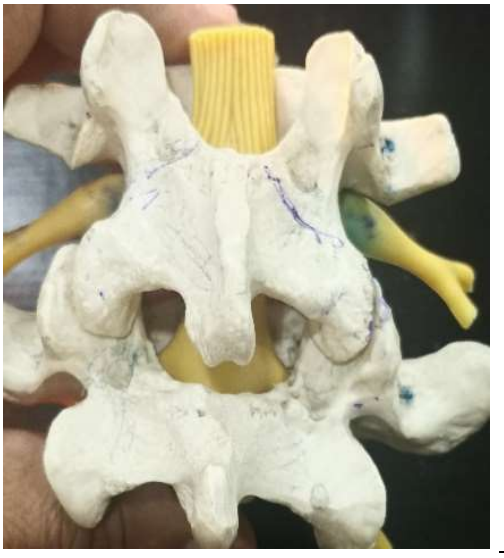


Image 6: our access at SAP tip leads to this, seen from below body of L5.

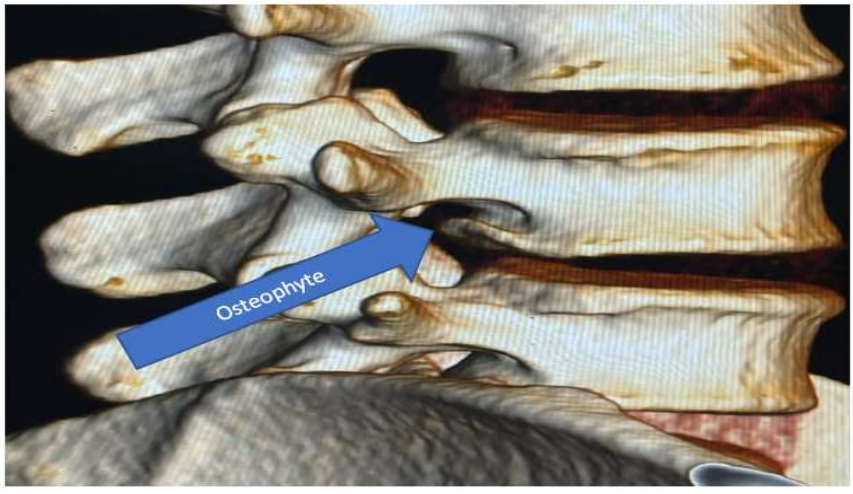
Image 7 8 coronal and sag view of the upper zone in a model.



UPPER zone is farthest from interlaminar access.

Soft tissue: Walls and Ligaments: There is NO disc or facet joint in upper zone. Upper border Ligamentum flavum [medial part] has attachment to VENTRAL face of upper lamina in its caudal part where it covers middle zone. Upward oblique lateral ligamentum flavum LATERAL TO FACET EDGE and in about 80% comes in roof of the upper zone and may affect the exiting root or the ganglion. It may continue outside the foramen as intertransverse ligament. In this zone disc margin can give osteophytes at upper mid zone border. The osteophytes are known to push the root and drg up towards pedicle and crowd them. Commonest location of osteophytes is paracentral where PLL covering annulus is weak and easily gives way. Normally SAP tip lies in line with lower endplate line but the hypertrophied tissue from SAP tip to cephalad pedicle comes sub pars. Upwards moving SAP if disc is collapsing with its soft tissue above and medial adds to crowding. It can be part of central subarticular stenosis where contiguous ligamentum flavum may be involved.

Image 9 Osteophyte from lower endplate crowding upper zone.



Lateral. Tissue knot laterally between lower endplate and SAP tip WRT exiting root and area caudad to it. THIS is common in chronic micro instability where the foraminal ligaments, annulus, capsular tissue amalgamate to form a G [gore] knot in foramen T5.

Most common targets T1 are soft tissue in upper "foramen" needs soft tissue foraminoplasty.

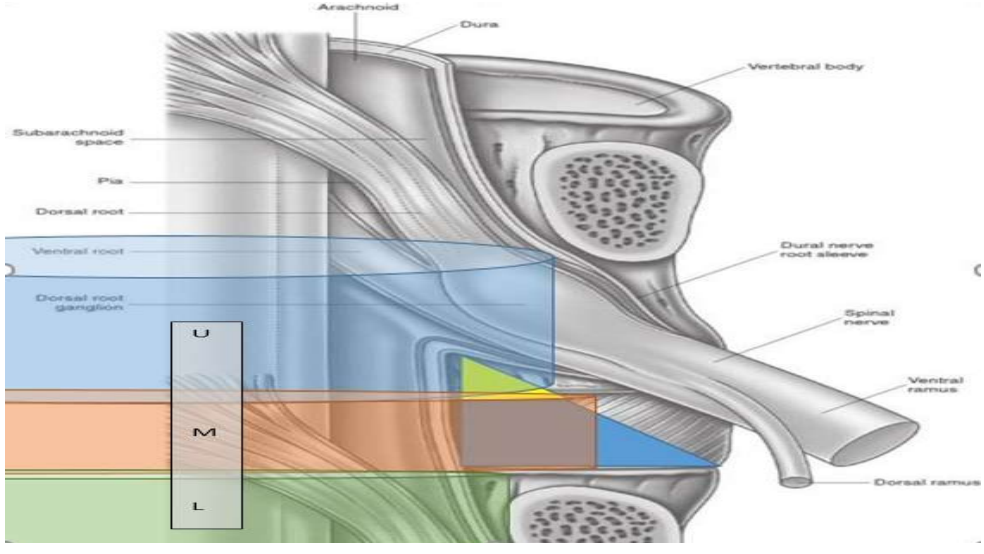
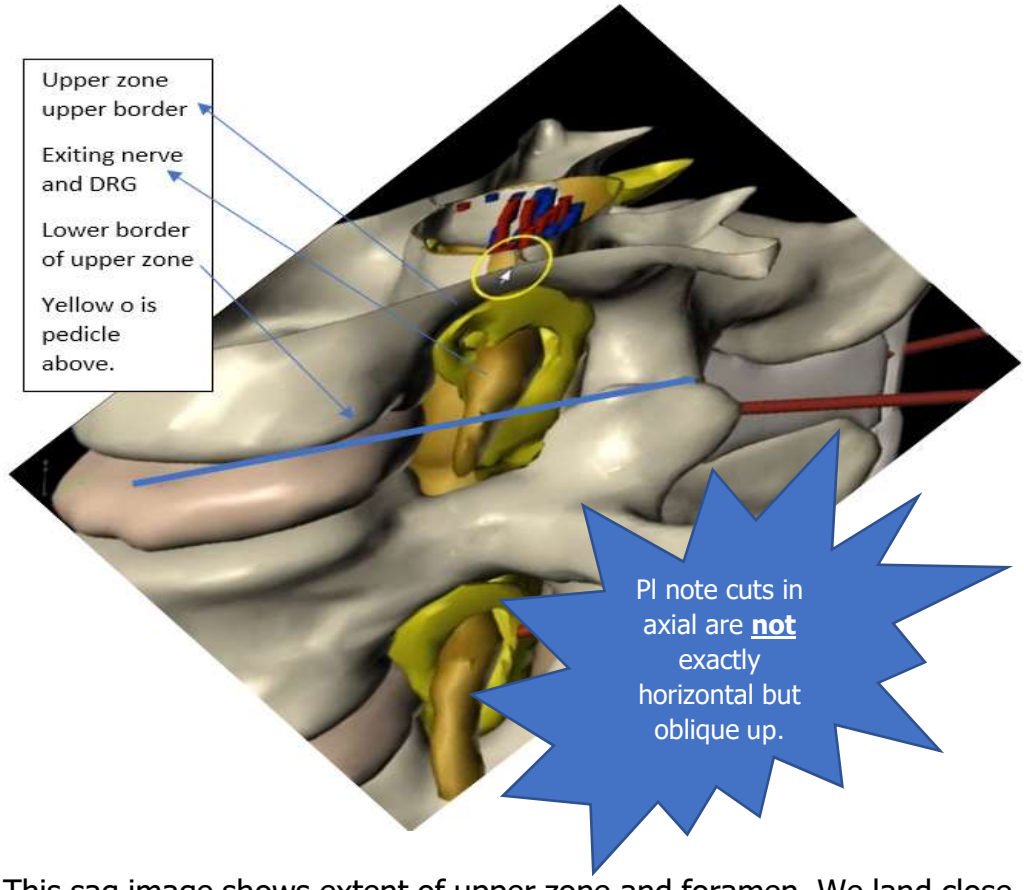


Image 10. Kambin's safe triangle and 3 zones in 2d.

3D images that follow are from our landing at end plate and go uptowards pedicle above covering whole UPPER CANAL zone.The 3d models images are mainly to highlight precision needed. IT is to bring into focus our targets for treating stenosis and its relation to nerve tissue around. This may help in prevention of complications. It adds precision.

Images of 3d model with focus on targets in upper zone. IMAGE 11



This sag image shows extent of upper zone and foramen. We land close to blue line or its lower border. WE always land in axilla of the exiting nerve, but is very close to DRG in its lateral wall. Appropriate use of transparent cannula can give a better view of the anatomy of surrounding tissues. AWAKE aware patient helps and adds to safety.

Most of the work is towards tip of SAP so we turn cannula with its tang or tip towards axilla, open bevel window faces the SAP. It is important to note that SAP tip is almost always in line with end plate and in collapsing disc it comes up in upper zone. Normal distance between cephalad pedicle and SAP tip is close to 7-9 mm.

Image 12 SAG OBLIQUE cut at border between upper and middle zone at end plate of disc.

Some brown ligamentum flavum seen sub pars. Yellow o is end plate of the vertebra and is our landing area.

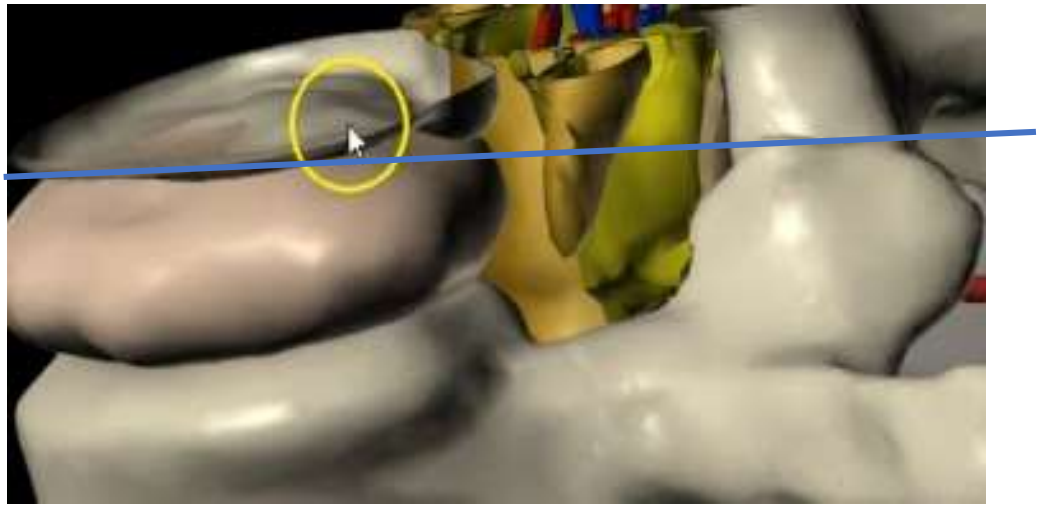
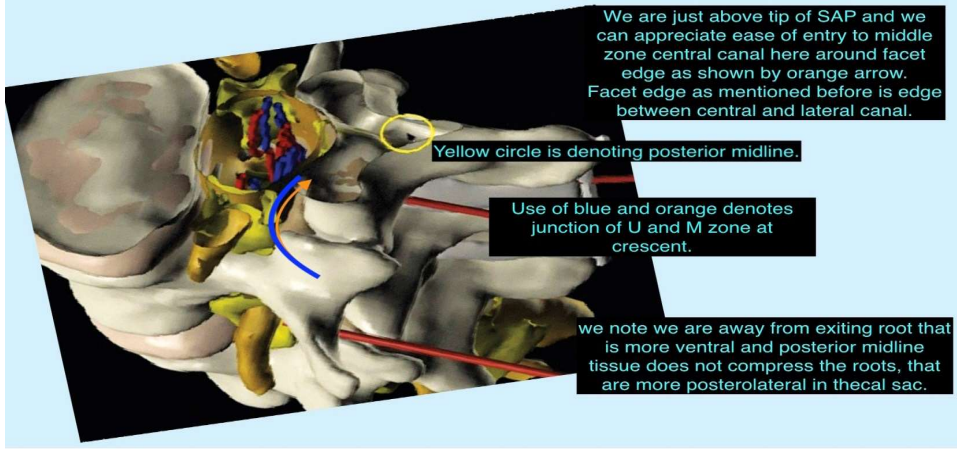


IMAGE 13 SAG cut seen at lower border upper zone canal.



Blue crescent area is important border area between upper and middle zone on SAP tip. Now we go upwards, NERVE ROOT HAS LEFT, WE ARE IN AXILLA. Once we are above SAP it gives easy access to medial face of facet joint to treat central "middle zone" stenosis.shown by blue crescent in image 13.

IMAGE 14 Axial cut at SAP tip level.

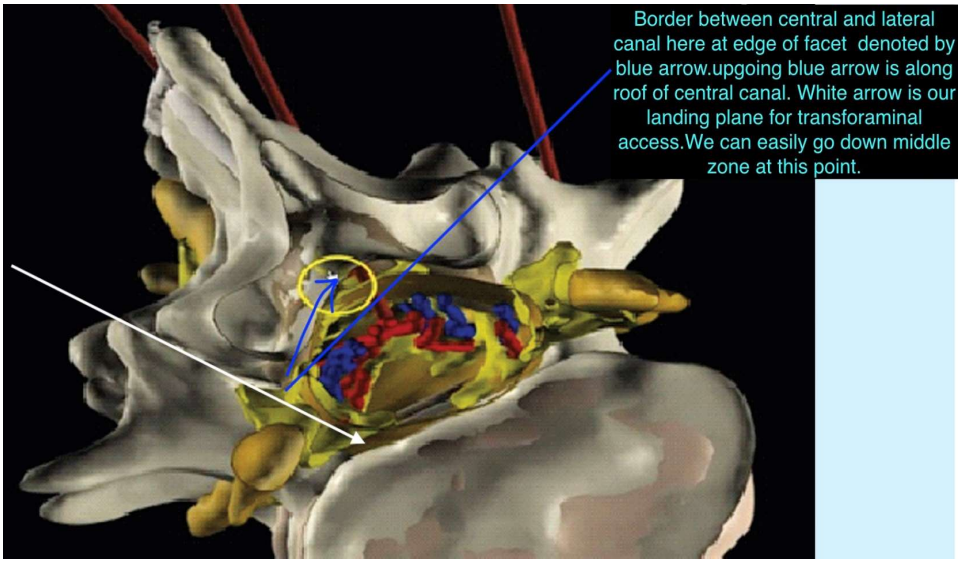


Image 15 SAG cut at lower border of upper zone or IEL. SAP tip seen .

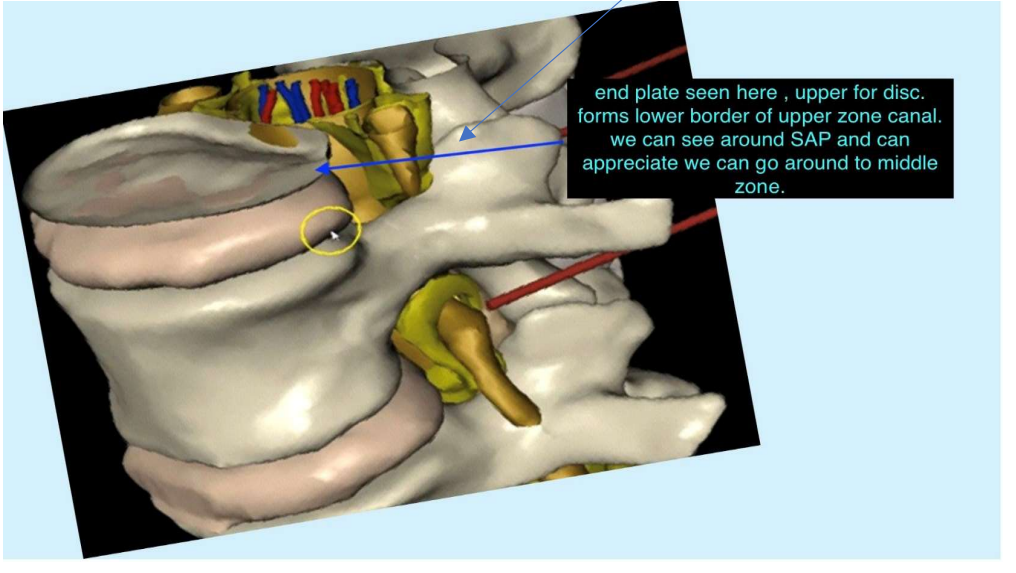
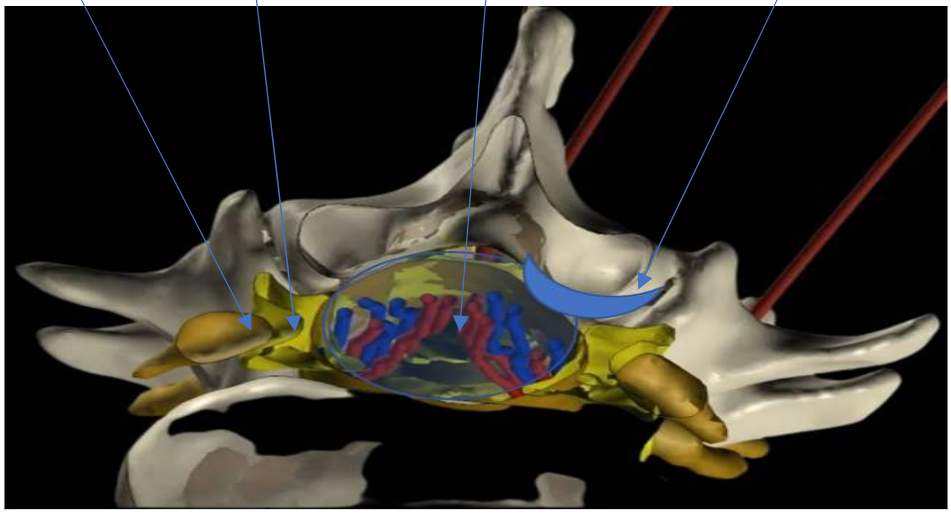


Image 16. Axial cut closer to end plate of vertebra or lower border upper zone.

Sap tip will come in view in roof and disc in floor. Full AP height of foramen seen. Axilla. Upper zone canal thecal sac. Roof tissue. Disc o.



CANAL of upper zone. MAIN area with symptom causing change : Disc is absent.[osteophyte may be present]. Facet joint is absent. Ligamentum flavum medial part is absent. ONLY lateral part in roof can add to symptoms. Blue circle is thecal sac in canal. Blue crescent is lateral ligamentum. These axial cuts are not exact horizontal plane but little oblique up posteriorly so some inaccuracies in seeing the structures is likely.

Image 17 Axial cut of upper zone.

Superior view of axilla. NO FACET joint or disc seen. Ligamentum at roof in 80% seen. IAP of vertebra above seen clearly.

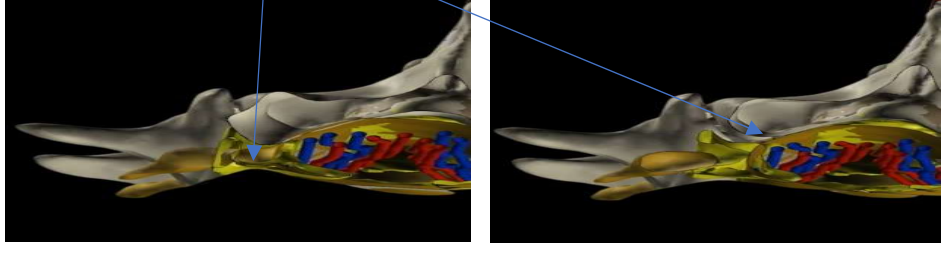
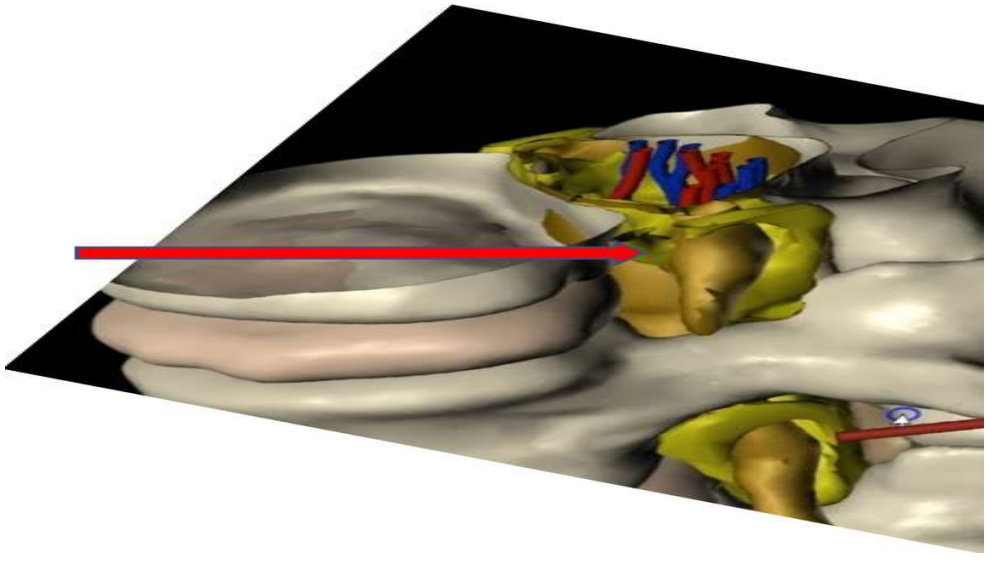


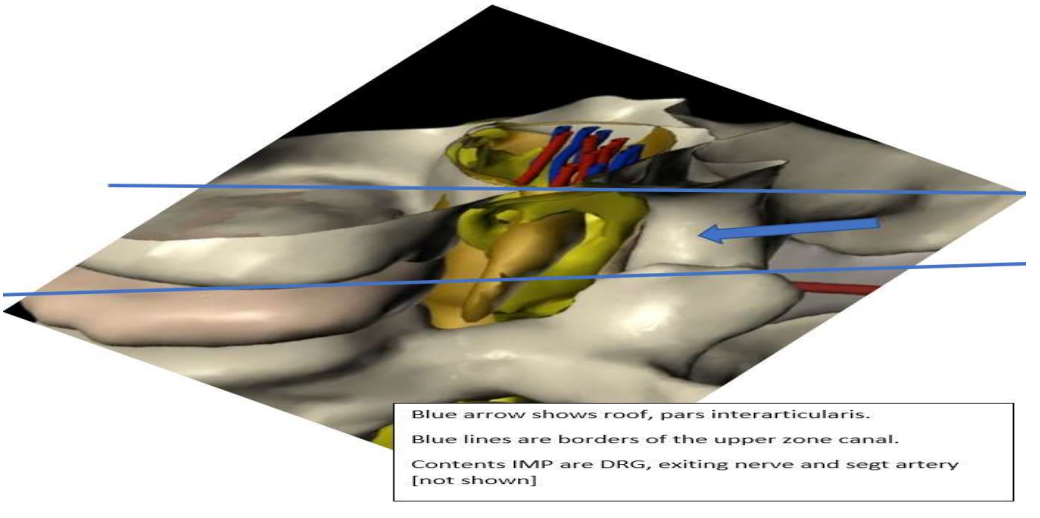
Image 18. Caudal section red arrow showing segmental artery location.



WE ARE caudal lateral to EXITING ROOT HERE. We have the artery shown as red arrow. It is close to beginning of upper zone. Artery perforates inter transverse ligament in its proximal part, distal part of intertransverse ligament is perforated by dorsal ramus going dorsally.

Image 19 Sag cut of the upper zone seen through foramen.

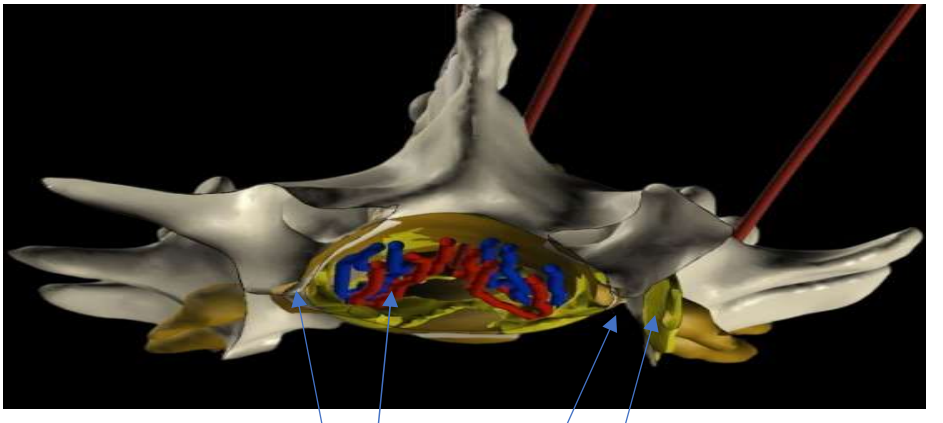
Pars shown with blue arrow. We may have T 2 target here in lytic pars. This lies dorsal to DRG.



Transforaminal surgery is under local anaesthesia is inherently safe. In upper zone when we decompress the DRG we can see its free pulsations, these are transmitted from close by segmental artery. Improper handling of the DRG area leads to severe post op dysesthesia. Recent advent of wireless DRG stimulator are put ventral to DRG for control of chronic pain.

Image 20 axial cut.

Note exiting root close to pedicle.NO LIGAMENTUM FLAVUM HERE.



On right of image we see operculum of Forrestier and roof of upper zone foramen. We are on shoulder of exiting nerve. WE can see axilla very well between thecal sac and the exited root. We do see traversing roots inside thecal sac travelling down.

The 3d anatomy makes us aware of danger zone in upper zone close to pedicle containing segmental artery. WE also have DRG in lateral wall of our access area.

Surgery for upper zone:

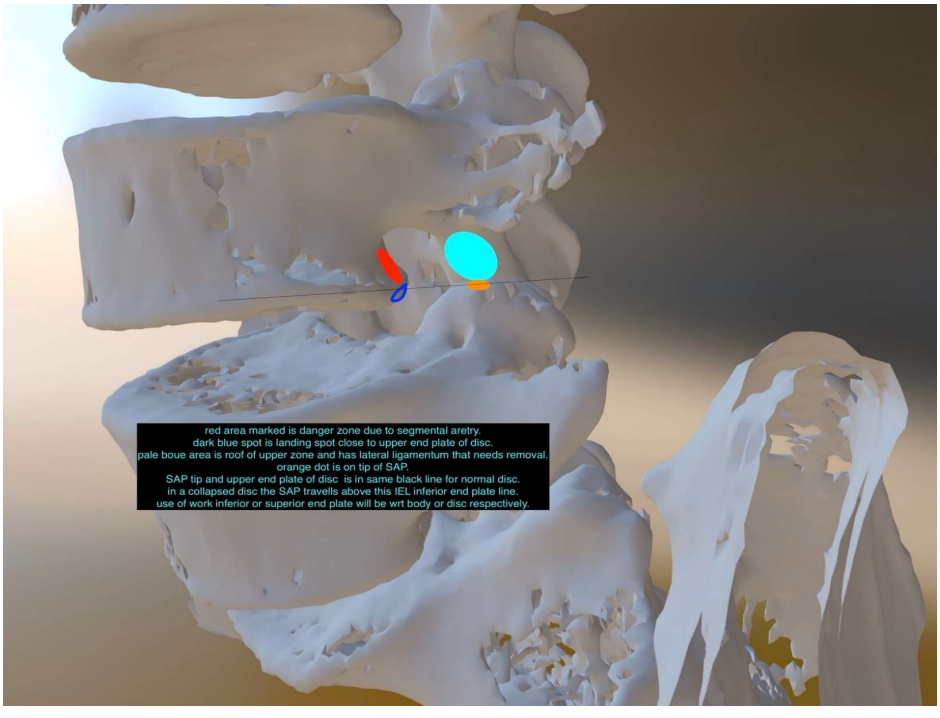


Image 21. Schema of TFE in upper zone. Target area is marked blue spot. [L45]

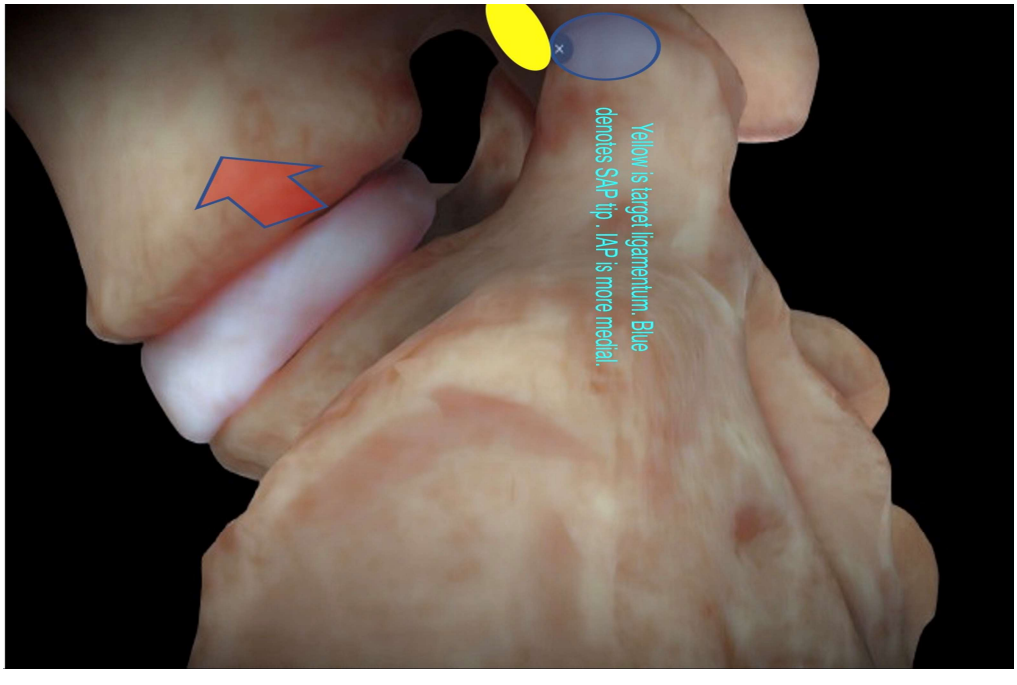


Image 22 Target area blue at L5S1.

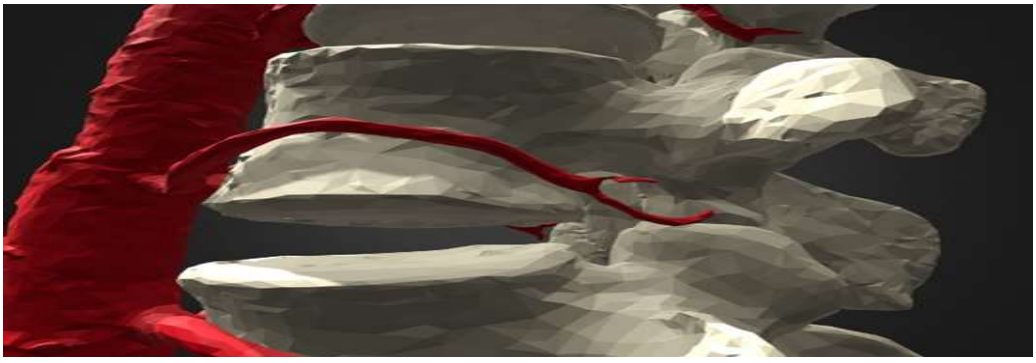
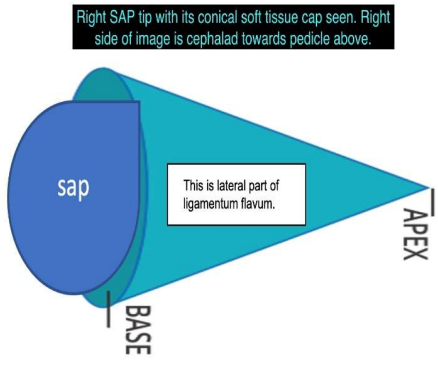
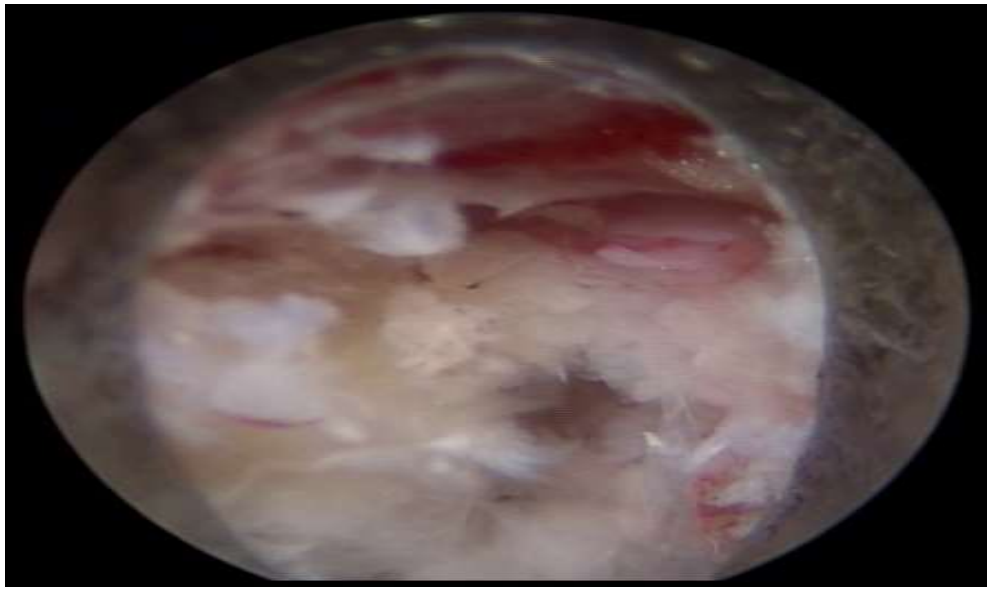


Image 23. Segmental artery course.

Image 24, 25, 26 Right SAP tip. Removed. CONE of tissue on SAP, removed in Op.

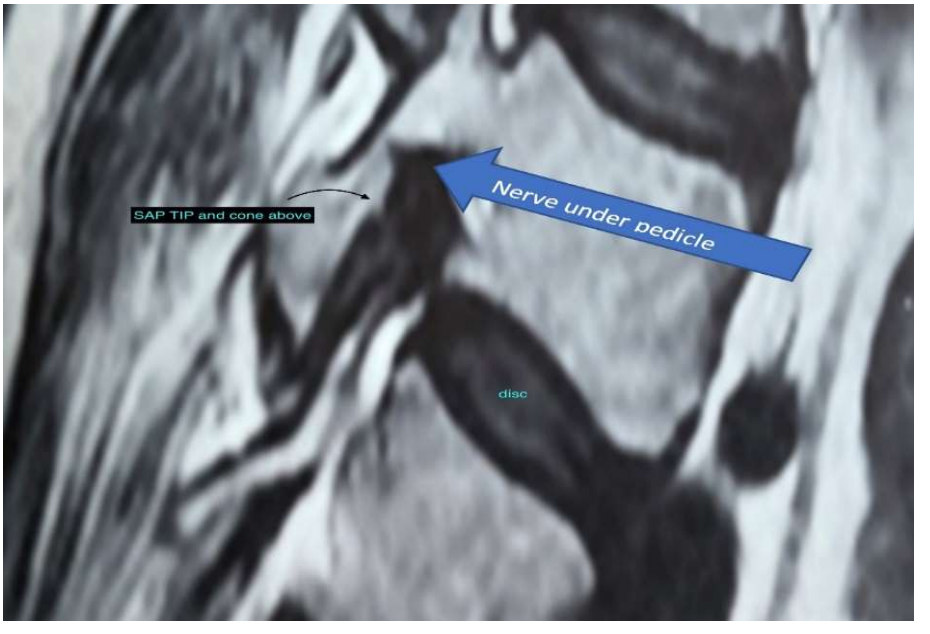


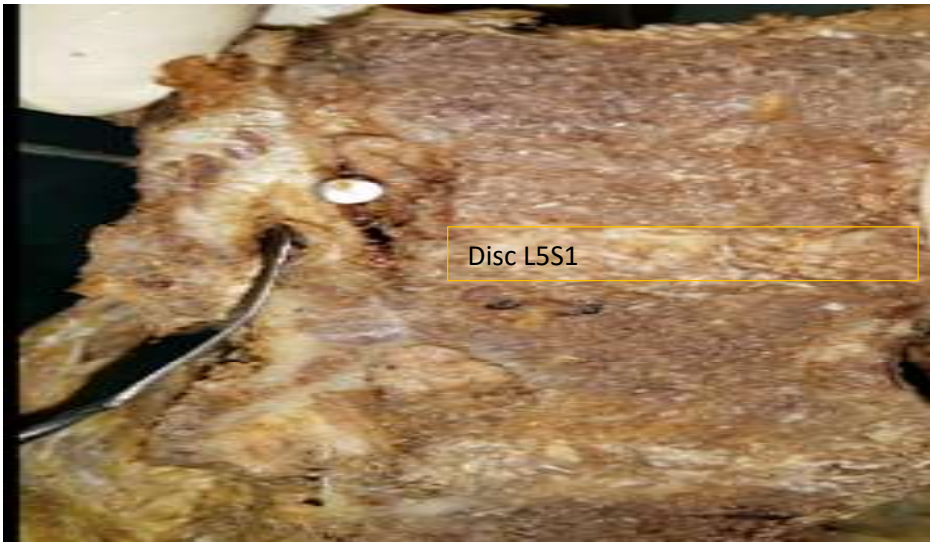


RIGHT SAP and cone on Sap towards axilla. Cone is soft tissue. Sap is bony. There is a distinct plane between that can be separated by use of hook. Cone lies completely in upper zone roof. BONY SAP is roof or posterior wall of middle zone.

Image 27 SAP and cone seen in MRI image. Sap body covers disc middle zone. Cone covers roof of upper zone.

Image 28 probe under superior foraminal ligament and flat probe in facet joint. Cadaver image.



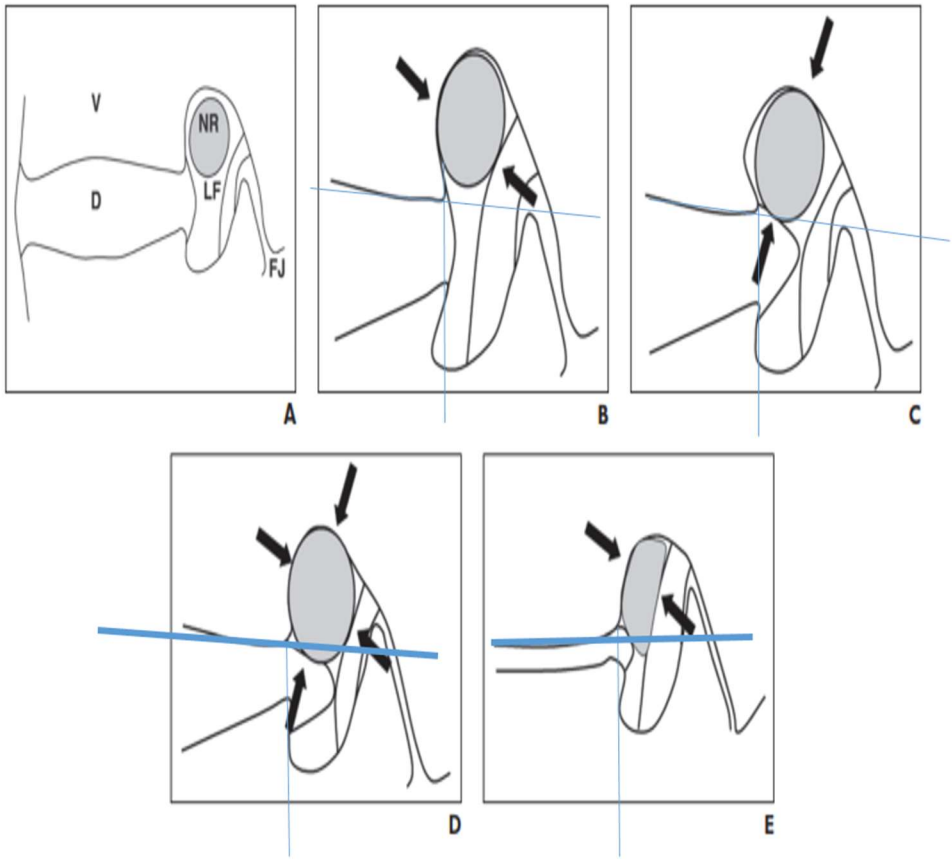


FORAMINAL stenosis classification. Classification by Lee.

A Grade 0 is normal sagittal cut at foramen. B Grade 1 mild foraminal stenosis perineural fat is obliterated in arrow directions. C Grade 2 mild fat obliteration above down. D Grade 3 moderate fat obliterated in all directions. E Grade 4 Severe stenosis due to ligamentum hypertrophy, facet soft tissue hypertrophy, collapsed disc and additional osteophyte at disc endplate. Line drawn along lower end plate of vertebra and posterior wall of vertebral body can clarify changes in grades A B C D E of foraminal stenosis.

Image 29

Lee classification of foraminal stenosis grades A to E.



Steps of upper zone surgery:

1. Percutaneous entry by 18 G needle under awake aware conditions done with guidance of C arm imaging.
2. Land in middle discal zone closer to cephalad endplate. Go cephalad to endplate to upper zone canal. SUPEROLATERALLY in floor upper zone contains segmental artery and DRG.
3. We look for tip of SAP that is dorsally in line with end plate, in collapsed disc it comes in view more easily and cephalad to our landing. Rotating cannula towards head will show tip of SAP dorsally. During surgery rotate open part away from axilla.
4. Upper zone targets in stenosis are tackled by soft tissue "foraminoplasty".
5. We do not need to be inside upper zone canal. For middle zone access we can go above and inside SAP. There are no [DISC FACET LIGT] symptom generators in upper zone inside canal. This area also may harbour various inflammatory foci below related to disc or facet and give inflammatory radicular pain treated by peri radicular infiltration of steroids or PRP platelet rich plasma.
6. We can use straight curette intradiscal on endplate in case of osteophytes. Removal of osteophyte is done intradiscal by scrapping. Soft tissue on pars is scraped by using curette or ablated with plasma cautery or laser. This is against bone of IAP and pars it is safe.
7. During surgery we use curettes working right or left on tip of SAP to cut it and scrape off the soft tissue. We then trace the ligament caudal and inner face of the facet.

8. Going more medial and under surface of IAP is safe along roof.
9. We stop if we visualize the DRG or pulsating soft tissue. It is extremely risky to go cephalad to DRG due to presence of segmental artery.
10. The tissue covering SAP is like a cone. Capping SAP. We start working on its base first by creating a tissue plane between apparent base of cone and bone below.
11. Then we work on its lateral face. We remove most of the cone matter pointing towards axilla. Base bone is curetted out by using twisting movements of opposite cupped curette, right side SAP tip needs left curette.
12. The LIGAMENT TISSUE on inner face of Sap leads further caudally to middle zone, location of central canal stenosis. Upper zone decompression complete on cutting SAP tip.
13. In upper zone roof area, the sub pars ligamentum flavum is in 3 layers as seen from foramen.
14. Superficial is horizontal like a sheet and may be part of operculum and peri dural membrane. Middle is vertical hanging from roof and sap tip. Deeper horizontal layer is likely to be adherent to dural sac, and pulling at this deeper ligamentum flavum is painful. This deeper portion is contiguous with ligamentum that forms wall of central canal pincer.
15. Since patient is awake and aware during surgery a safe access and a natural neuro monitoring is possible and patient can report in real time. I use transparent working sheath WITH NEUROMONITORING [PATENT PENDING] or cannula to visualize the anatomy well.

16. Post op dysesthesia is likely if we work too close to DRG or in a very stenotic foramen or use high energy modalities like laser or RF plasma near neural tissue or use excessive sedation or anaesthesia to avoid procedural pain and handle tissue too much.
17. This can be avoided by rotating tang of cannula towards head, to protect the DRG while working on SAP tip and tissue on and around it.
18. Adequacy of surgery is known by pulsating DRG seen at end of decompression.
19. Upper zone roof at L45 is known to have furcal nerves towards roof, travelling dorsally ACROSS in view, distally joining L5. Anomalous nerves explain pain better than images.
20. DRG is situated in this zone and neuro-augmentative therapies are evolving. We as transforaminal endoscopists are best positioned to deliver them.
21. Note of caution: To avoid complications surgery MUST be done under local anaesthesia with conscious sedation. In stenotic foramina aggressive push towards canal is to be avoided. Use of high energy modalities must be avoided under general anaesthesia.

Decompressing axilla by removing Sap TIP CAP CONE tissue T1, treating T2 at pars completes upper zone decompression. In middle zone central stenosis surgical access to middle zone is above SAP tip in addition to ventral facet and edge undercutting. WE must guard against exiting nerve injuries by doing surgery under LA. Pre op counselling about higher chance of dysesthesia in tight stenosis is mandatory.

Illustrative case: 1

Illustrates hypertrophied ligament at roof of upper zone as seen in MRI image. We land in disc closer to upper endplate. We initially can land in foramen closer to facet ventral surface, then gentle depression towards floor; of the working cannula against facet at surgery is enough to reach tip of SAP. We work on sub pars tissue by using burr, curettes, and RF plasma devices. As we progress medially we do see under surface of the IAP. WE DO NOT HAVE JOINT HERE. We stop on seeing IAP.As we work against bony roof, it is safe to use scraping instruments. We see pre and post op images to clearly show what tissue is removed.

The exiting nerve is already sloping out and ventral to cannula so staying close to roof is safe and correct way of tackling this stenosis. Working directly on roof without anchoring in annulus is possible with use of extraforaminal "teku tech" fulcrum. Use of TEKU will improve our access and effectiveness. MOST times surgery in stenosis may be a mix of symptom generators in adjoining zones and all walls. Upper zone may be commonly associated with middle zone causes.

Basic landing in middle zone then excursion to upper zone, cutting Sap tip and entry and work in middle zone on medial facet face if need be is the basic strategy for COMMON combined upper and middle zone stenosis.

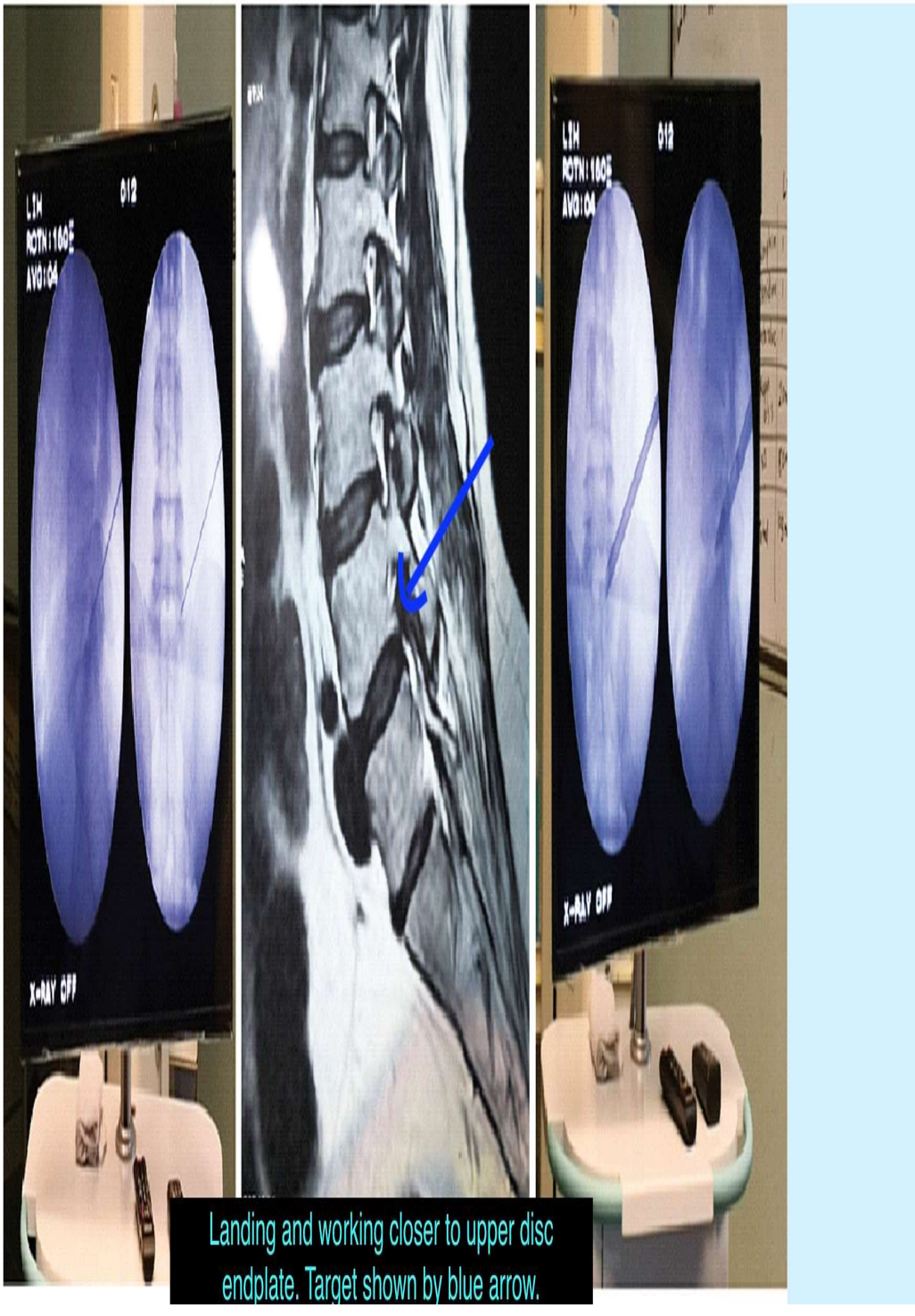


Image 20 Upper zone surgery part of TRESSULA.

Illustrative case 2: **LEFT** side access upper zone

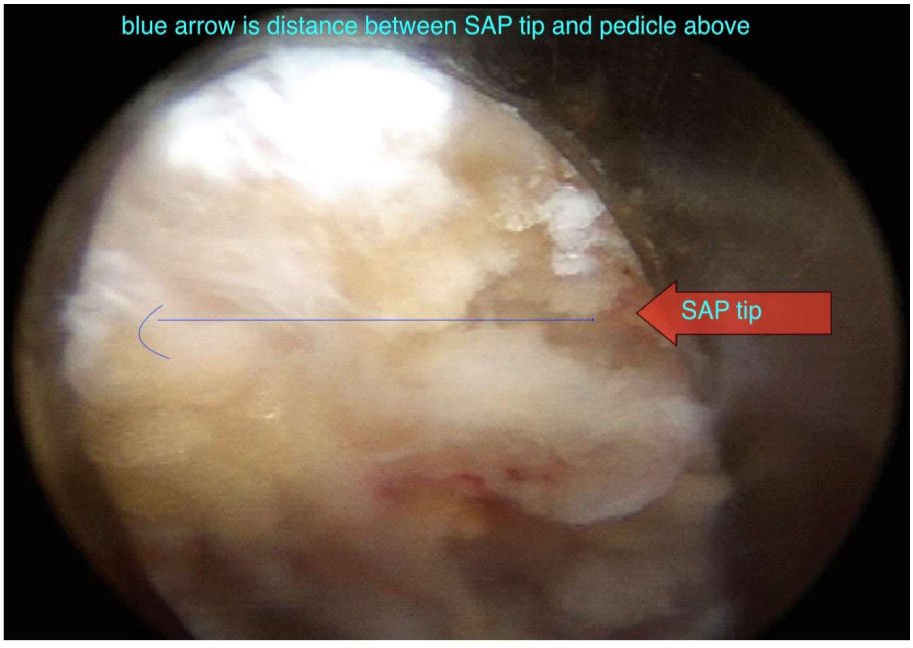
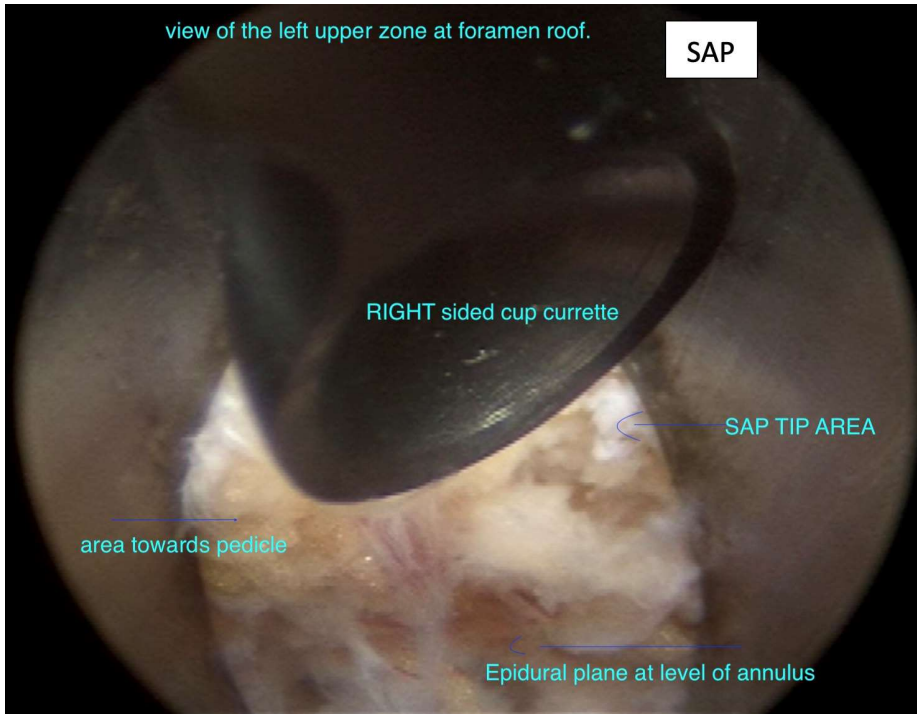
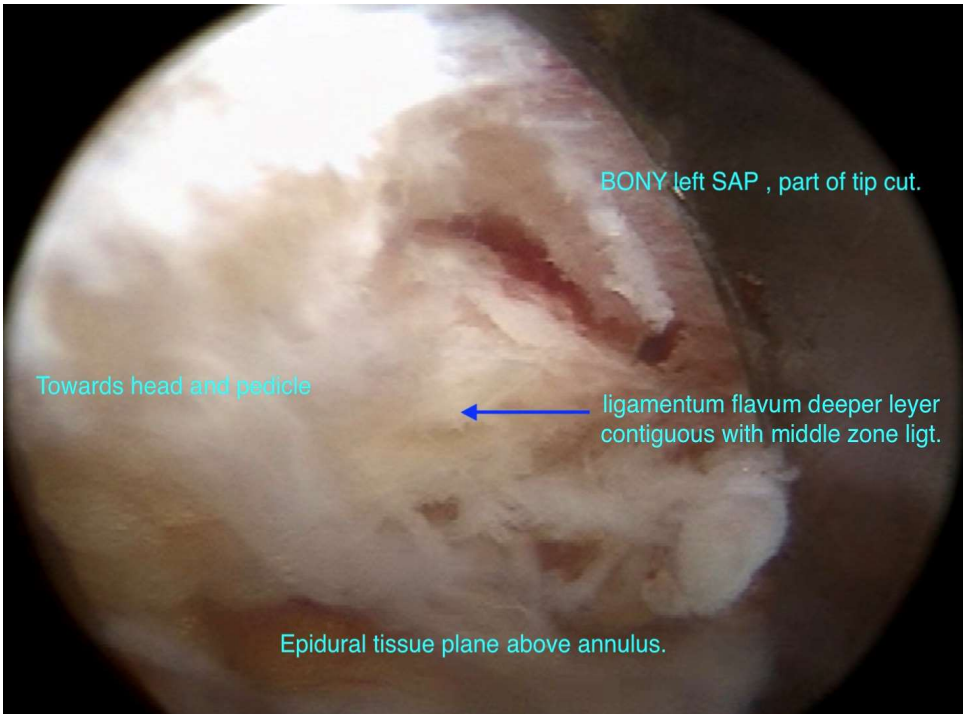


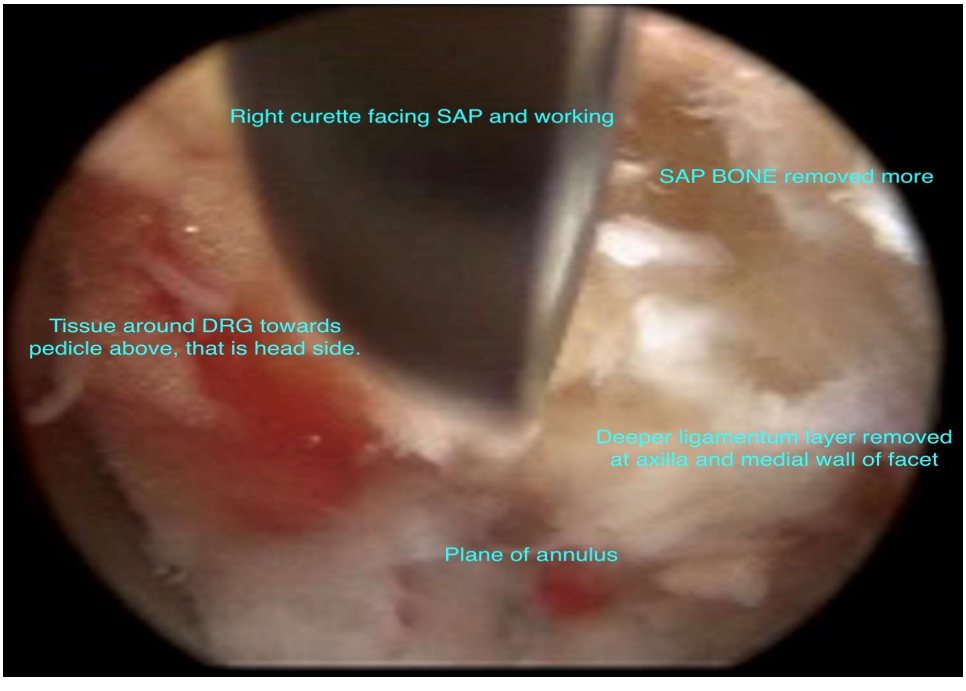
Image 21,22 Intra operative view left upper zone foraminoplasty.

RED Arrow on SAP , blue on target tissue: tip and pedicle above.



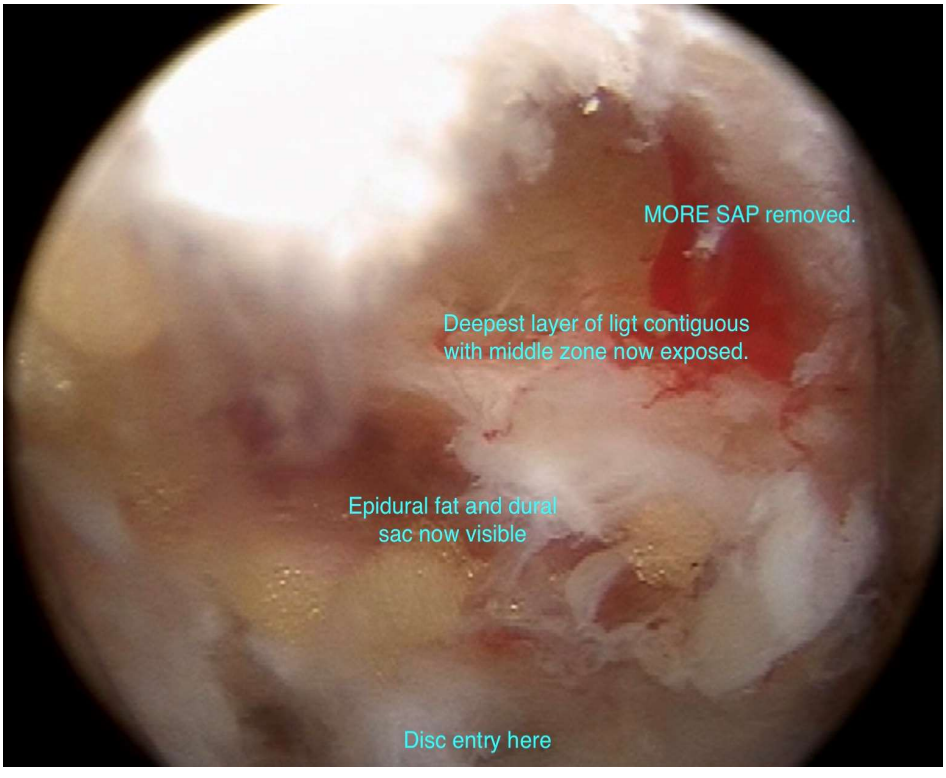


Images 23,24 Progressive removal of tissue stenosing in upper zone on left SAP.

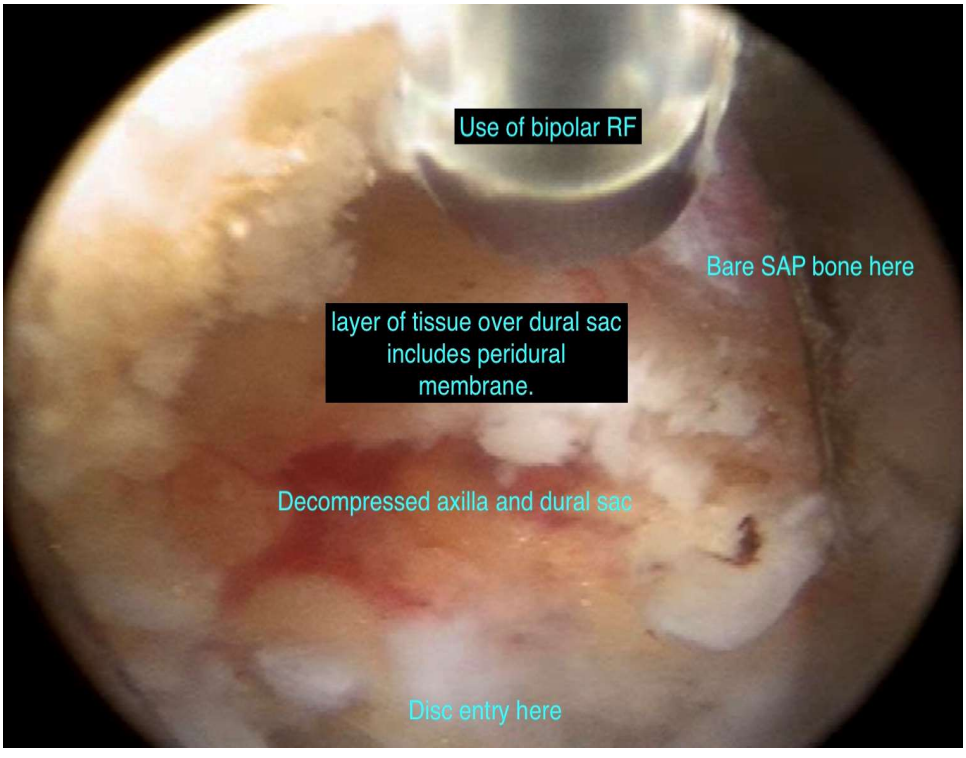


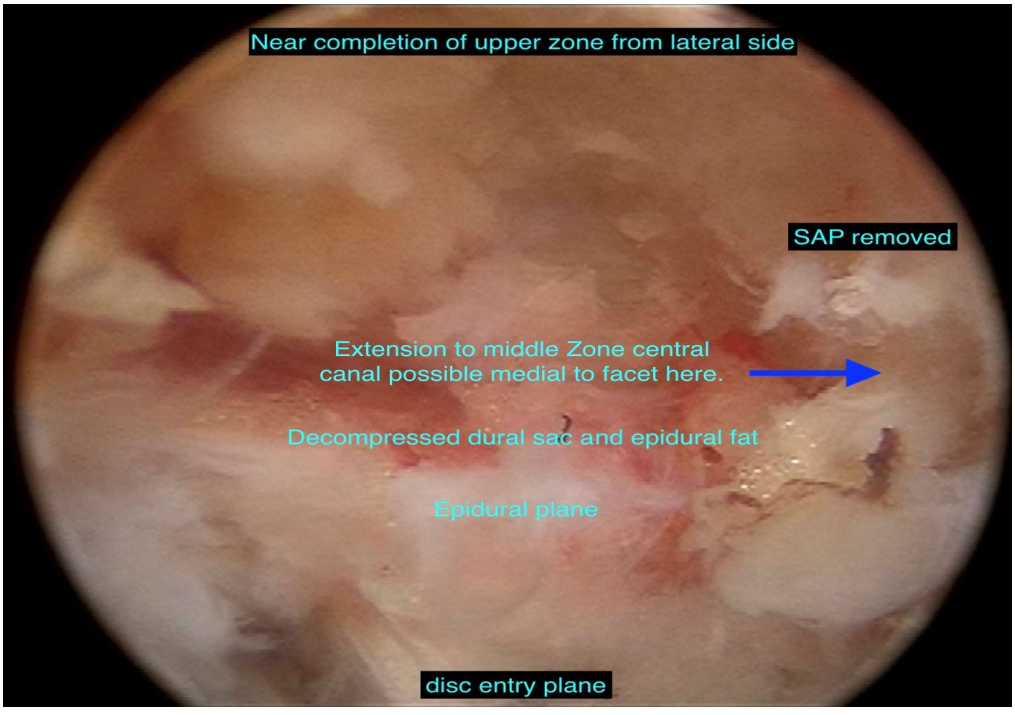
Use of curette, pic shows bare bone SAP tip. Next further bone removed.

We are working on left Sap tip with right sided curette.



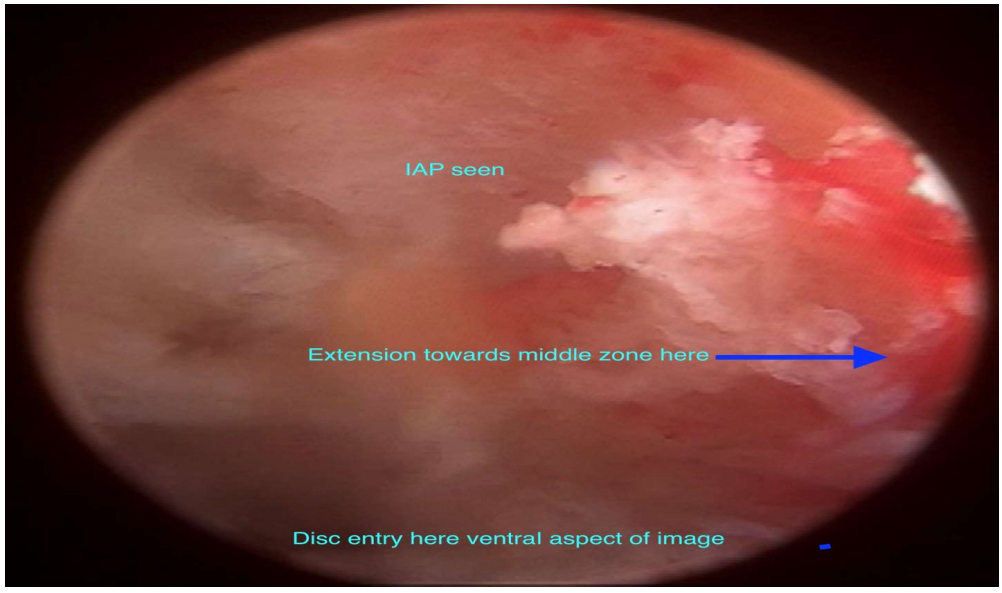
Images 25.26. We work on left upper zone.

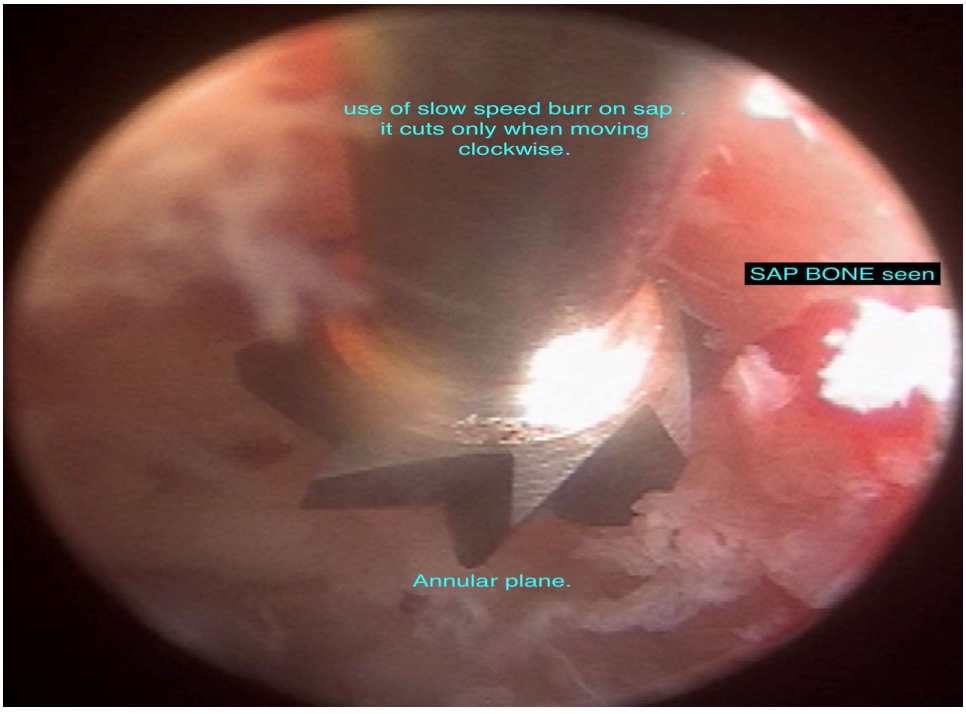




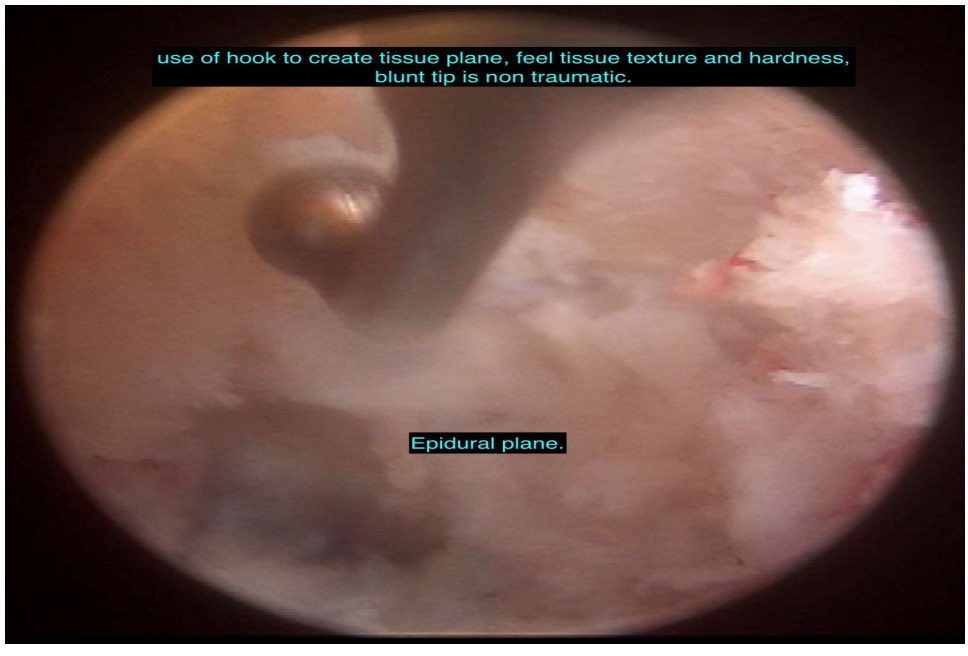
Images 27.28. Left Upper zone sub pars lateral decompression.

Upper and middle zone stenosis commonly seen together. Early exposure of traversing root/intrathecal. We may go around SAP tip and work on inner face of facet in central canal middle zone stenosis.





Images 29,30 use of burr and hook in left upper zone.



Nerve under tip of SAP. use of burr. use of hook for identifying tissue texture and surgical plane between bony SAP tip and ligament attached to it.

Illustrative Case 3: Upper zone surgery on RIGHT side.

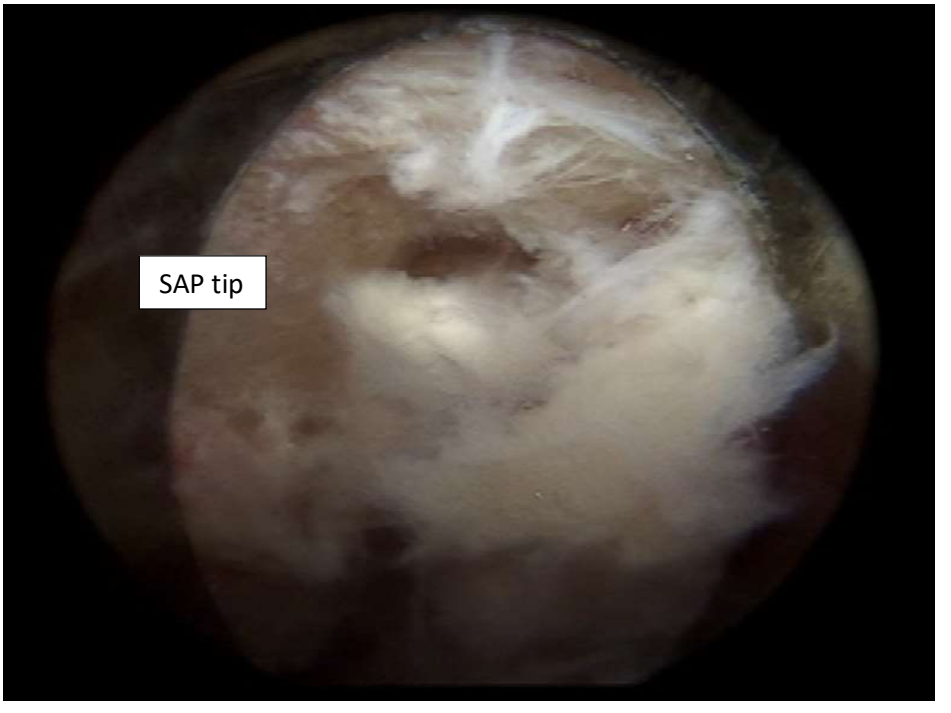
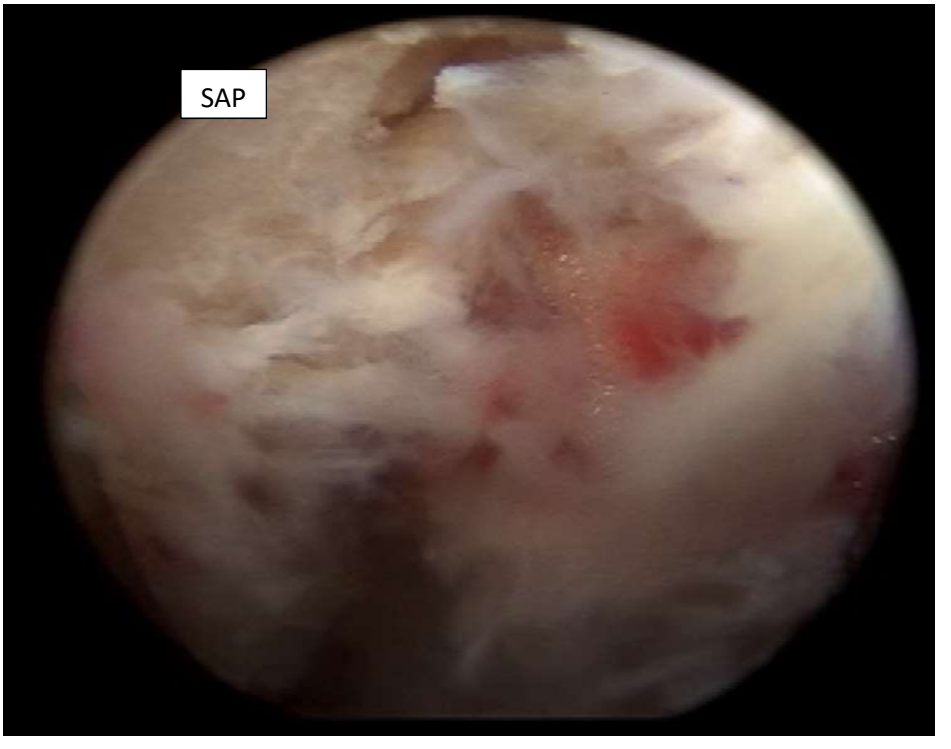


Image 31 Surgery on right side upper zone. SAP seen on left. Axillary tissue on right.

Image 32 Clearance of axillary tissue right side upper zone.



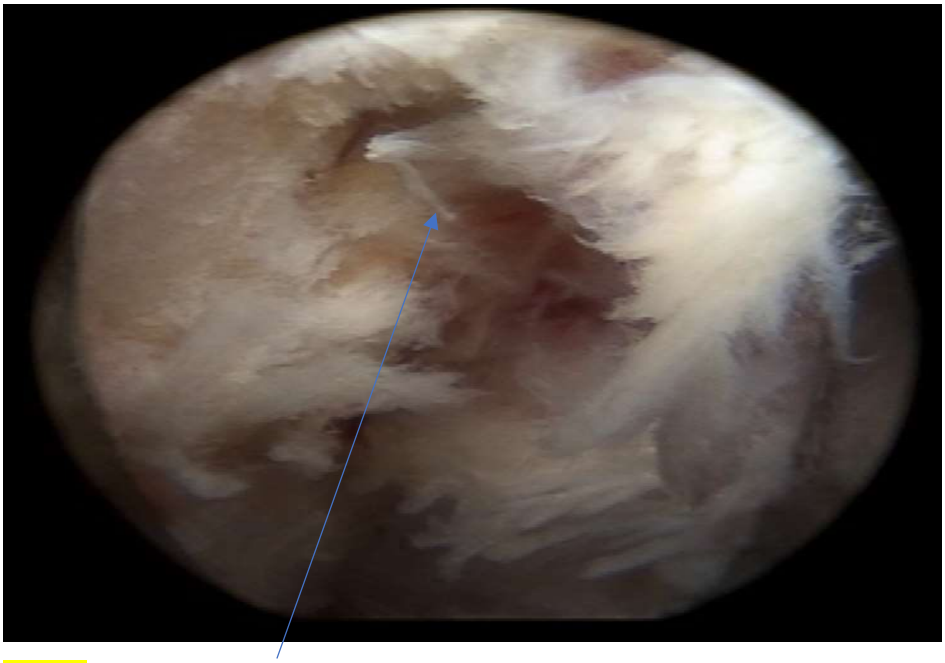
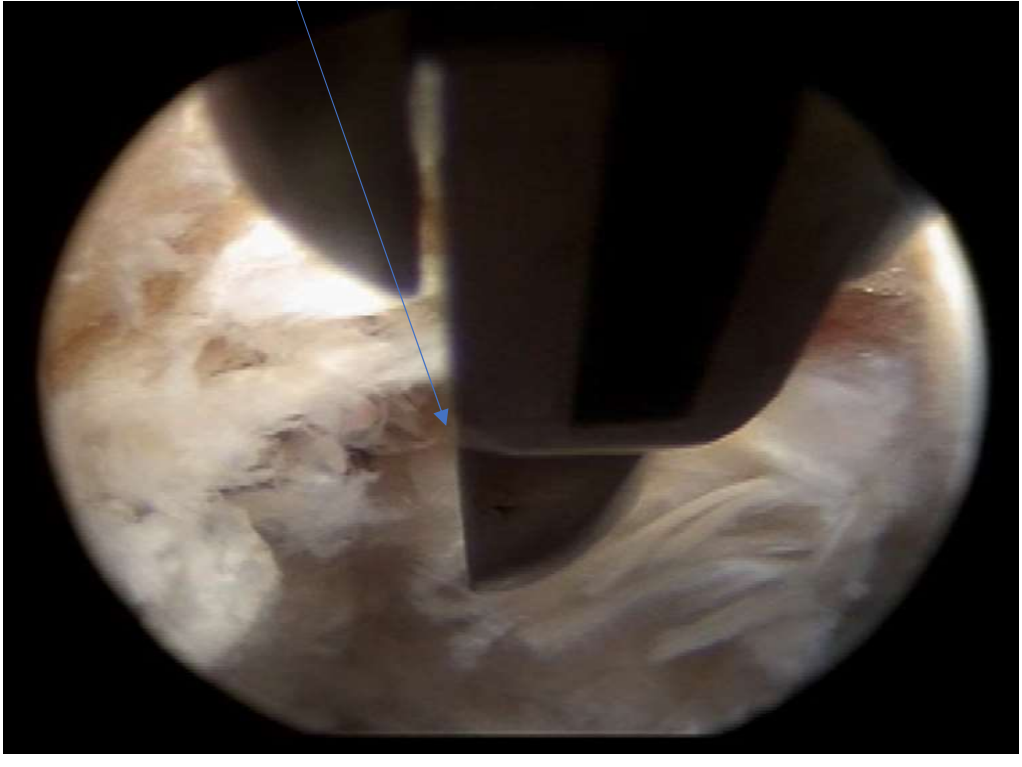


Image 33 Targeting SAP tip tissue right side foramen .

Image 34 Working with LEFT curette on right sided Sap tip now.



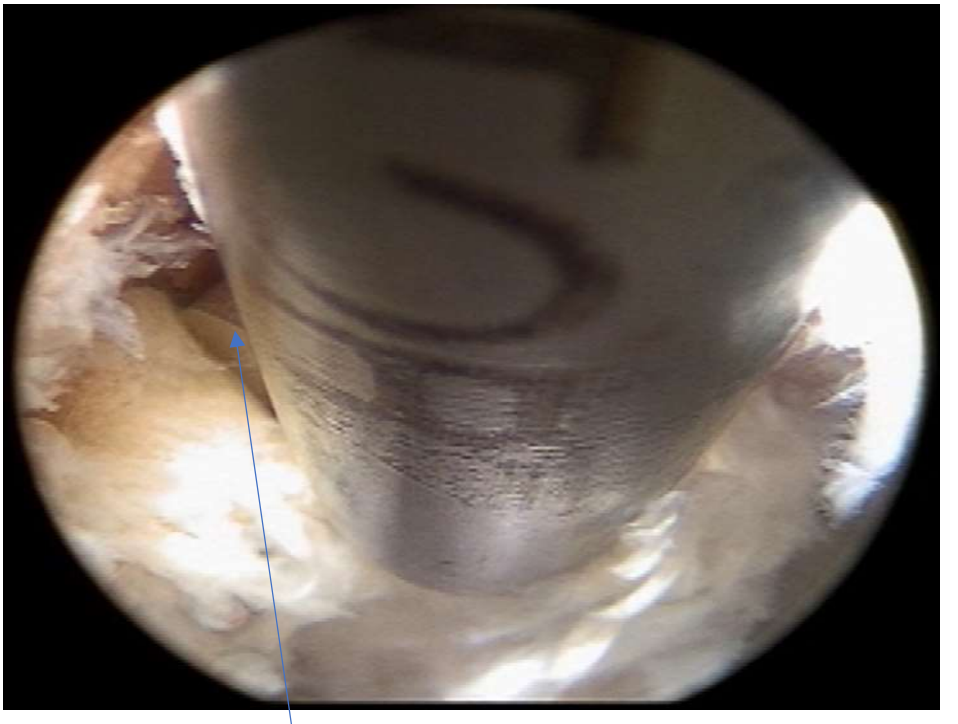


Image 35 Curette cup on SAP scraping off the tissue.

Image 36 SAP tip cleared, axilla on right 3 oclock. Tissue detached completely from SAP tip.

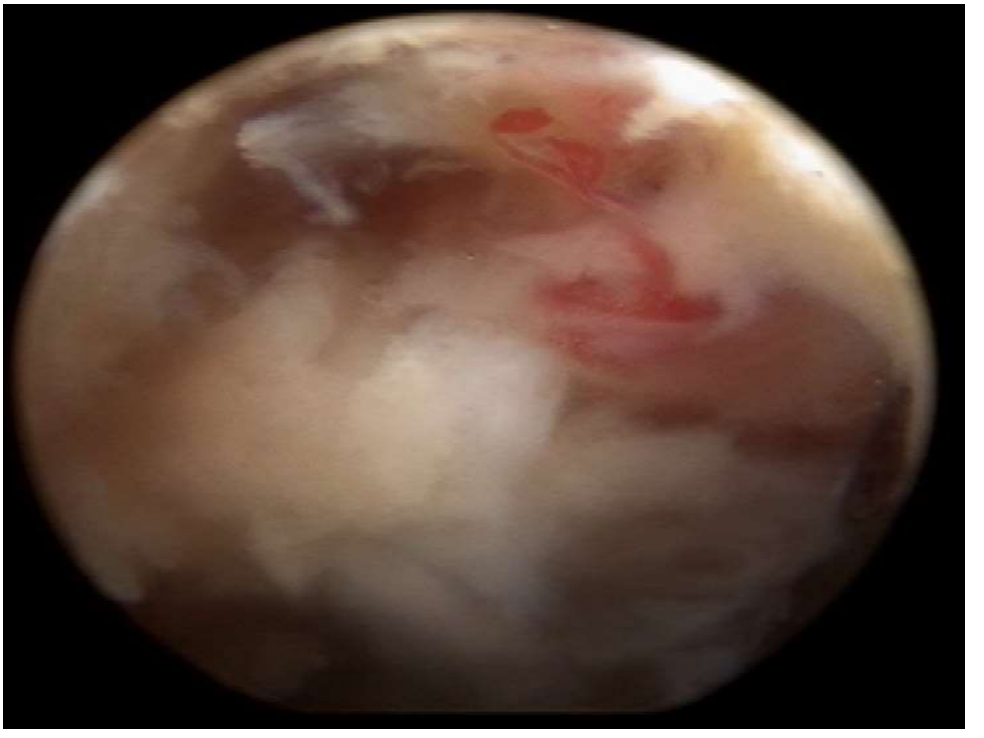


Image 37 Free axilla on right.3 o'clock. Blue arrow showing our plan to go inside Sap body on facet medial side.

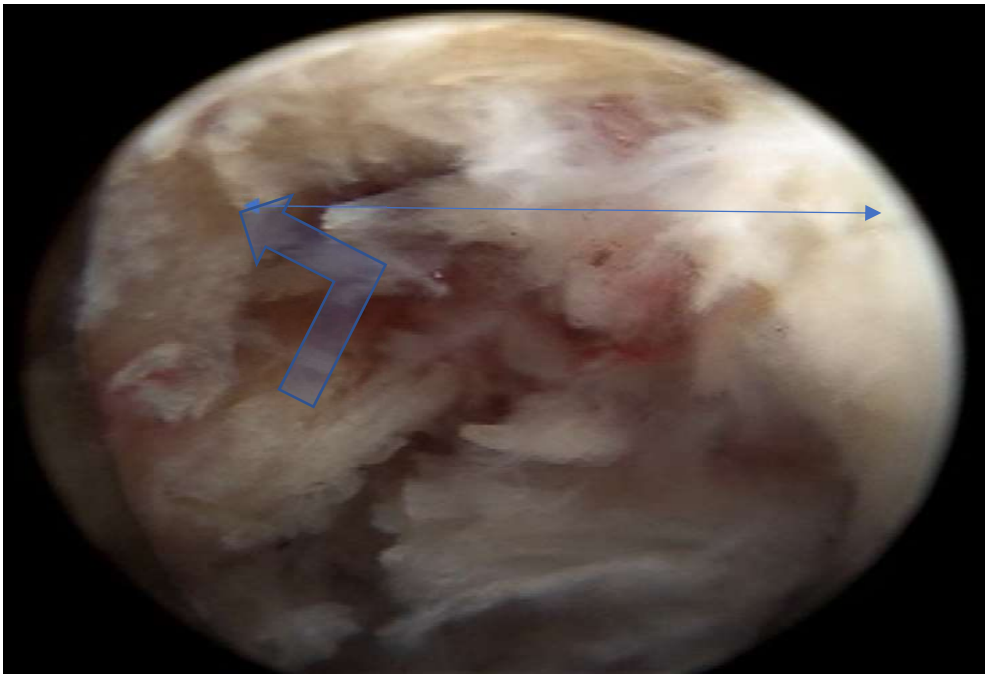
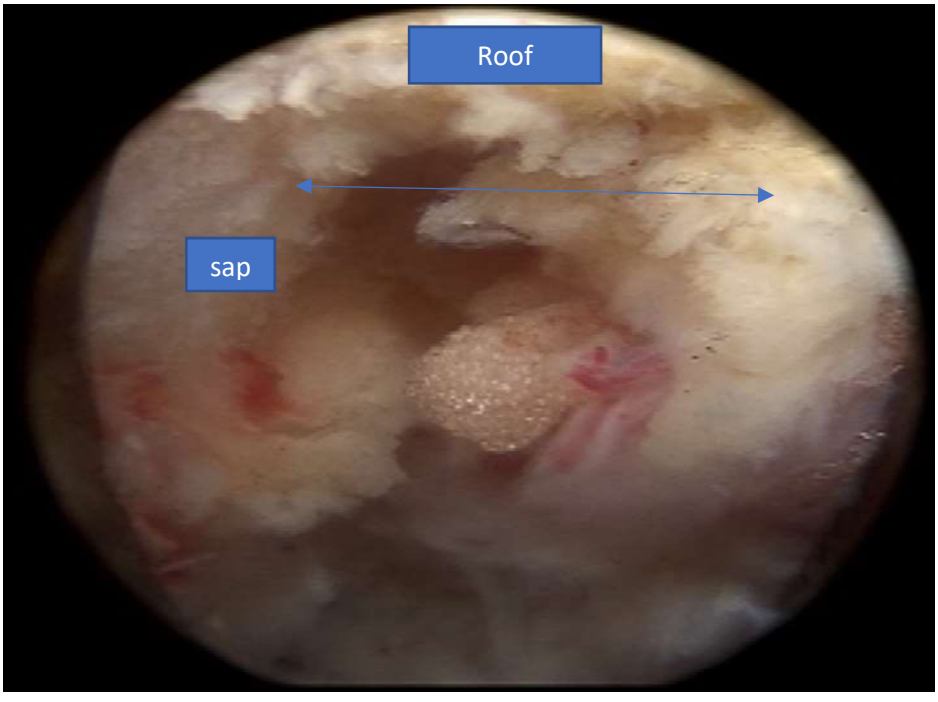


Image 38 Space between Sap and pedicle above to right increased. We can now go over inner face of sap to left for central canal.



We are still anchored in middle zone but working on upper zone.

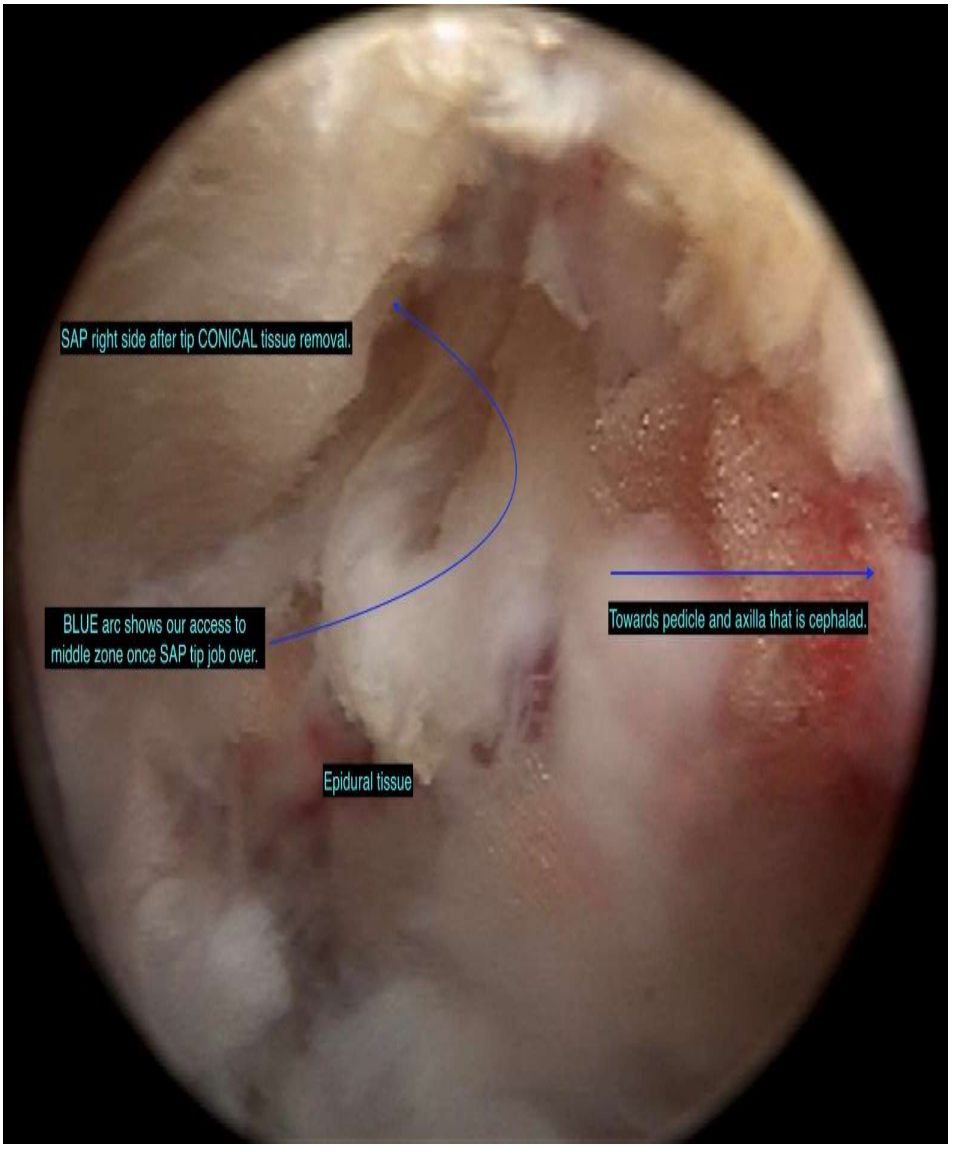


Image 39 Decompression of upper zone, axilla.

Summary:

Upper zone has no disc, no ligamentum in roof except lateral part. There is no facet joint. We go above Sap tip towards pedicle and decompress upper zone. It is soft tissue foraminoplasty. We may then cut bony SAP tip and go medial. SURGERY must be done under local anesthesia.

6 Extending reach to LOWER zone: Targets T 6 7 8

When we are referring to lower zone canal stenosis we need to be clear, it is not central canal but infradiscal extrathecal lateral canal or the traversing root canal stenosis. We are talking about changes in proximity of the root travelling along medial border of the pedicle and changes occurring along root canal walls. This also has been called as hidden zone of Macnab and lateral recess.

Lateral recess by definition lies lateral to facet edge. If we go posterior midline to access it we essentially have to cross the facet edge border and then go to lateral part of the canal. This crossing the border can only be done by more bone removal, potential instability and then added stabilization. In transforaminal access however it is easy. The local anatomy is demanding but is not impossible to access and address.

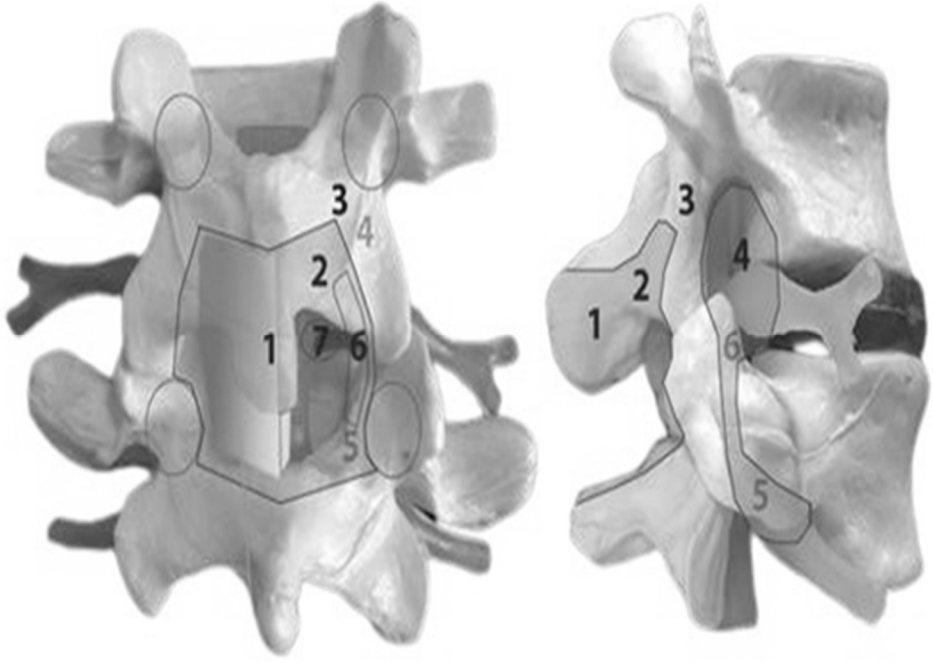
What is the importance of nerve root path? "Lower zone" or "lateral recess" or "root canal".

This is traditionally "hidden" but now manifest due to transforaminal endoscopy. E.g. This L5 root path around the pedicle in a bony groove can be divided in two parts according to access. Lower zone entry at L45 foramen is able to reach upper part 1 and 2 of this path. As seen previously upper zone entry at L5S1 is for upper zone sub pars part that lies caudal to part 3 of this path. Since the part 3 is asymptomatic and pure bony ring we do not have to access or address it.

We would like to highlight our ability thus to reach all parts 1, 2, 3 of the root canal or hidden zone with transforaminal endoscopy under local anaesthesia. This is landing in lateral canal and crossing its borders towards central without destabilizing the bony architecture. Let us see how we extend our reach from landing in middle zone to lower zone root canal or lateral recess, or hidden zone.

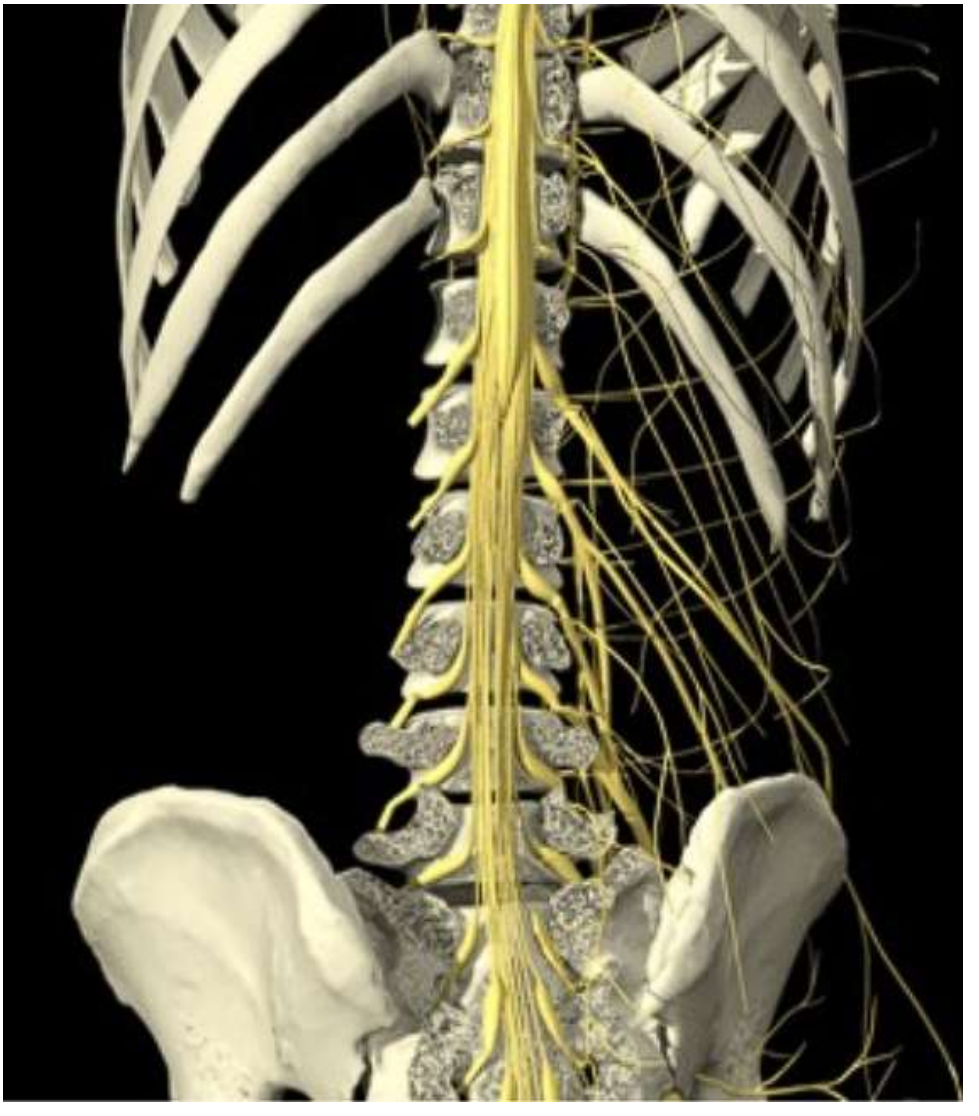
If you are from Traditional and a biomechanics dominated perspective, appreciate that our approach is fundamentally different. We are not concentrating on stabilization or decompression two main ideas in philosophy in open posterior midline surgery. We understand subtle changes and their progressive nature in proximity of nerve root path, resulting in symptoms of claudication. We identify locations of the changes in relation to universally immobile "fixed" portion of nerve root around the pedicle ALL WITHIN easy REACH OF FORAMINAL ACCESS. We also recognise the contribution of degenerative changes added to rare congenital narrowing of the bony canal resulting in symptoms. Resulting relief by decompression [not by mobilisation of roots], improving arteriovenous circulation around the axilla and the root is well REPORTED IN LITERATURE.

Image 1 Post midline decompression and lateral TFE.



Removal of 1 spinous process, 2 lamina to expose ligamentum 7 at its upper attachment. 3 pars is cortical bone and not touched 4 subpars foraminal & 5, 6 lateral recess decompression = pedicle to pedicle two root decompression. Transforaminal we do lateral decompression pedicle to pedicle under local anaesthesia. High chance of destabilization due to bony cutting noted in open access 1, 2.

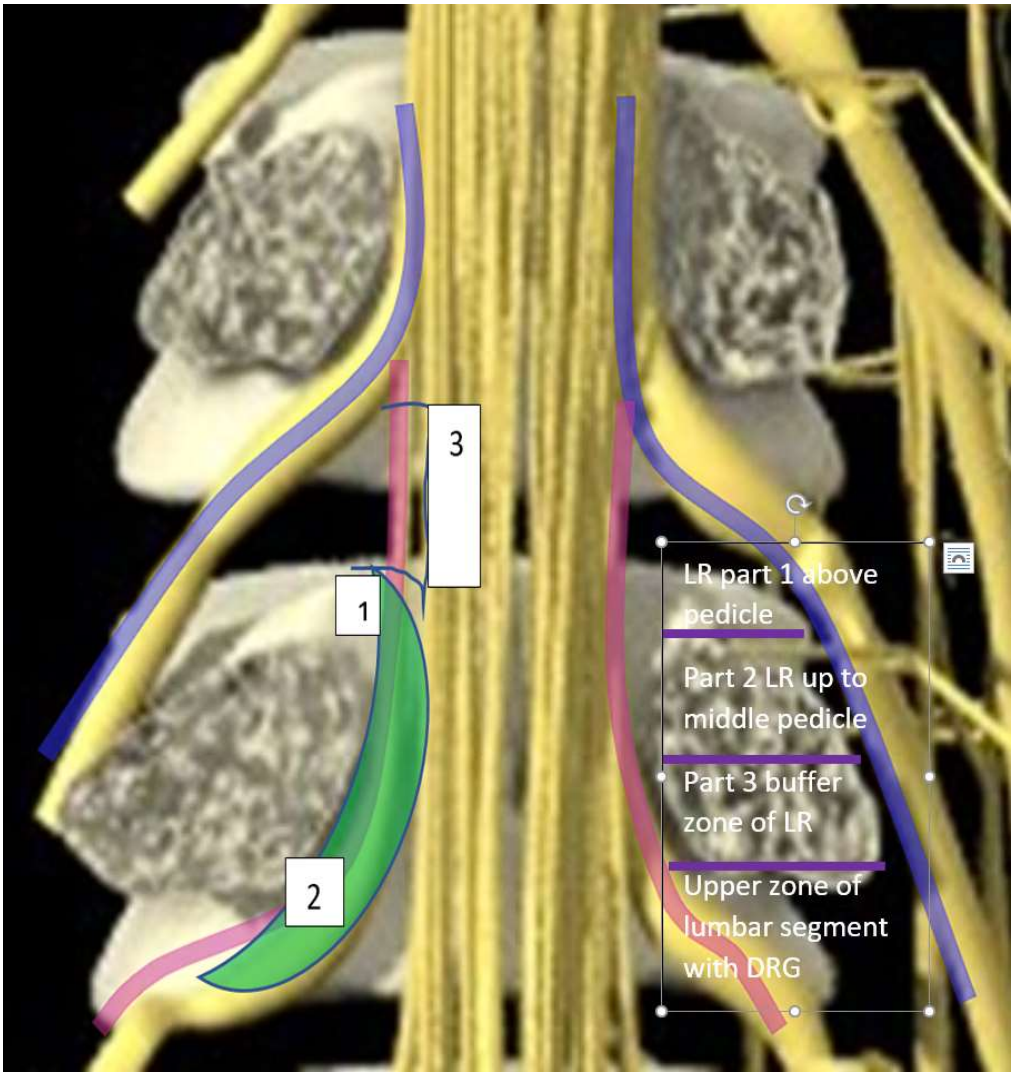
Image 2: Journey of roots, intrathecal [central] and extrathecal [root canals].



Conus and cauda and way roots travel in and after leaving dural sac.

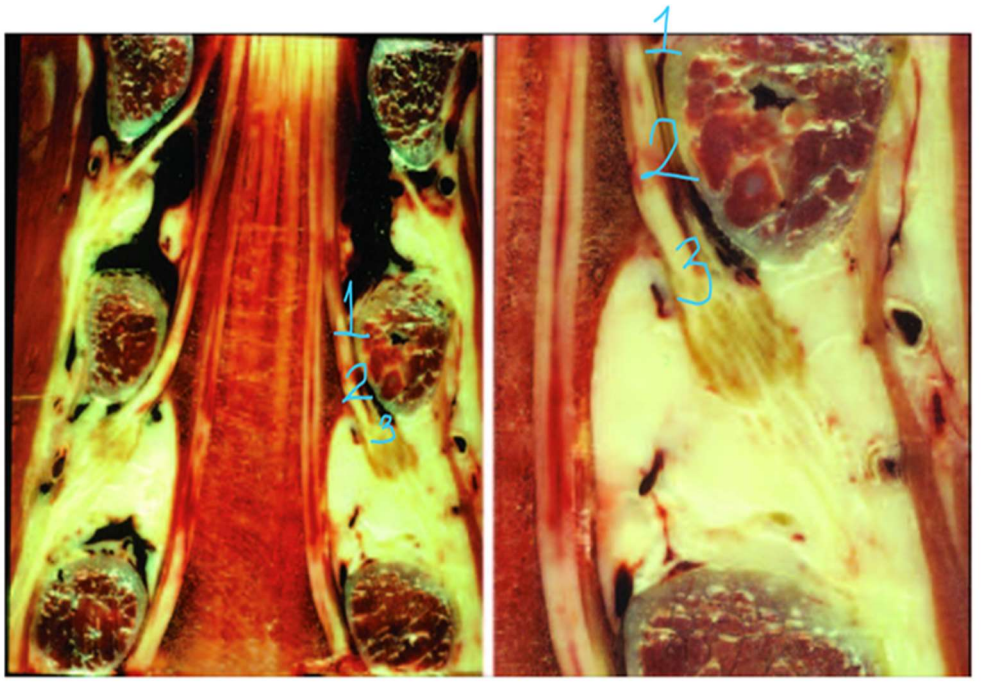
Intrathecal journey is free, mobile and padded by fat and CSF buffer towards external compression. Extrathecal Roots are relatively "immobile" in their journey around pedicle. Shown in image below as green area. This green area that lies in "lateral canal" with DRG is main symptom generating area due to changes in canal walls. DRG has been labelled as mini brain of functional spinal segment.

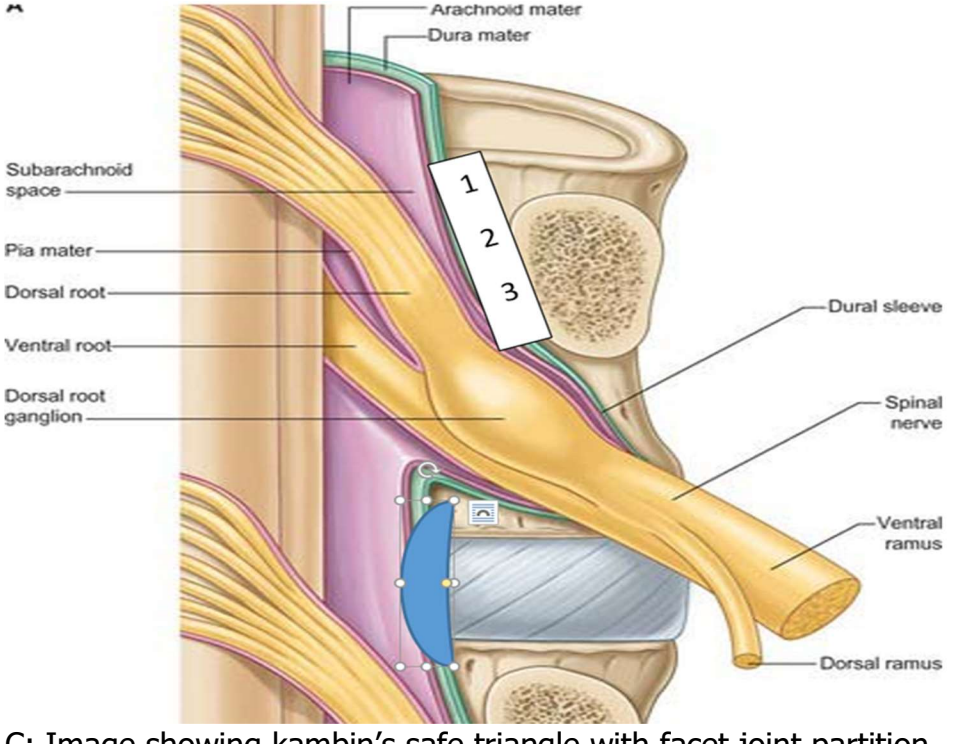
Image 3 A B C: Journey of roots and access to them.



In image see root in lateral canal or extrathecal journey.

B





C: Image showing kambin's safe triangle with facet joint partition between central canal and lateral canal.

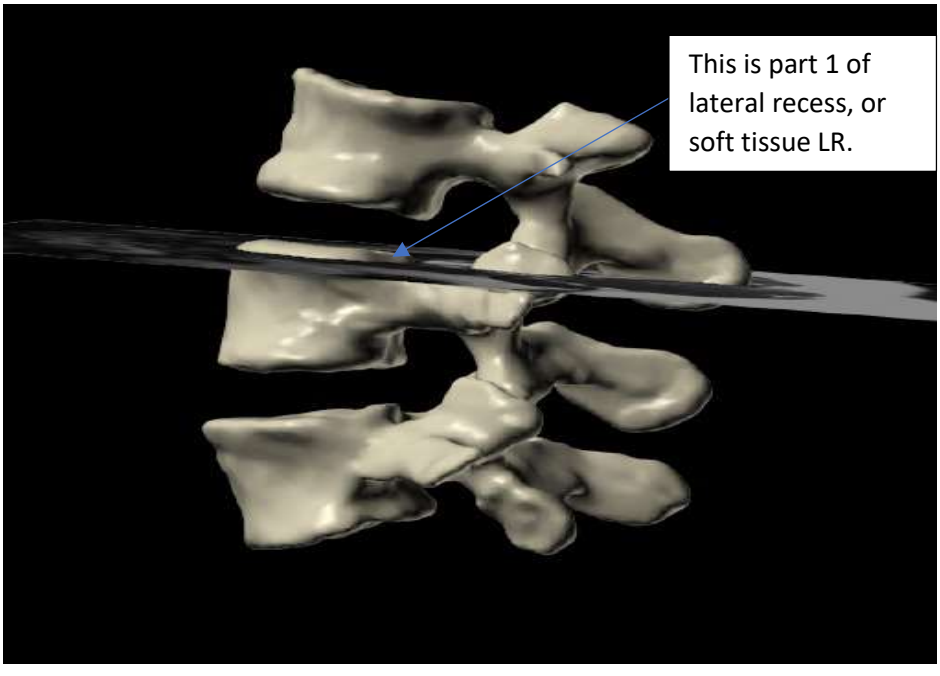
This partition is pincer arm. It also gives targets 1, 3, 7.

Shown on left of 3 A B. Image is of floor, work is on roof for 2.3. It may be at floor in 1. 1 is reached by lower zone access. For Extra thecal nerve root at entry to root canal.2 is reached by upper zone access. Extrathecal nerve root exiting from root canal in upper zone.3 interradicular intrathecal is reached in middle zone. 3 Intrathecal nerve root: central canal: middle zone

On right of image 3A: Functionally & structurally lower zone

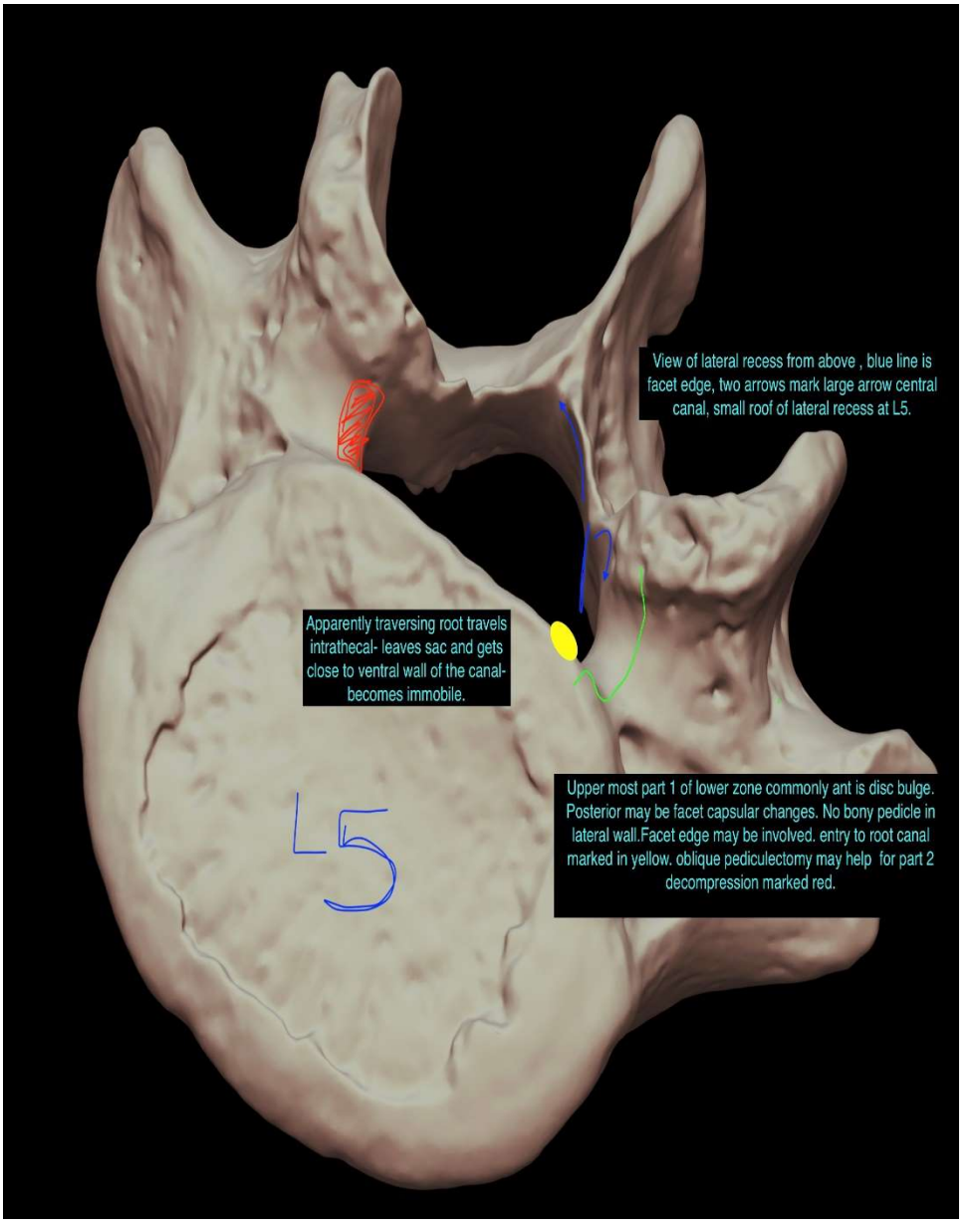
Part 1 lower end plate of vertebra to upper border of pedicle. Suprapedicular level [as seen in image below] is a thin section of upper few millimetres from endplate of the vertebra to the upper border of the pedicle, it has pouch of lower annulus and is soft tissue recess. It has clinical significance as commonest symptom generating area VENTRAL AND close to root entering root canal in lateral recess. Green in image below.

Image 4 soft tissue lateral recess.



Part 2 from upper border of pedicle to mid across pedicles line below mid across pedicle line is drawn bisecting pedicle in coronal view, it is border between part 2 and part 3 of root canal. 2nd part with upper half of pedicle as lateral wall is bony lateral recess. [Red in image below].Part 3 is buffer zone and functionally asymptomatic.

Image 5 Lateral recess or lower zone or root canal.



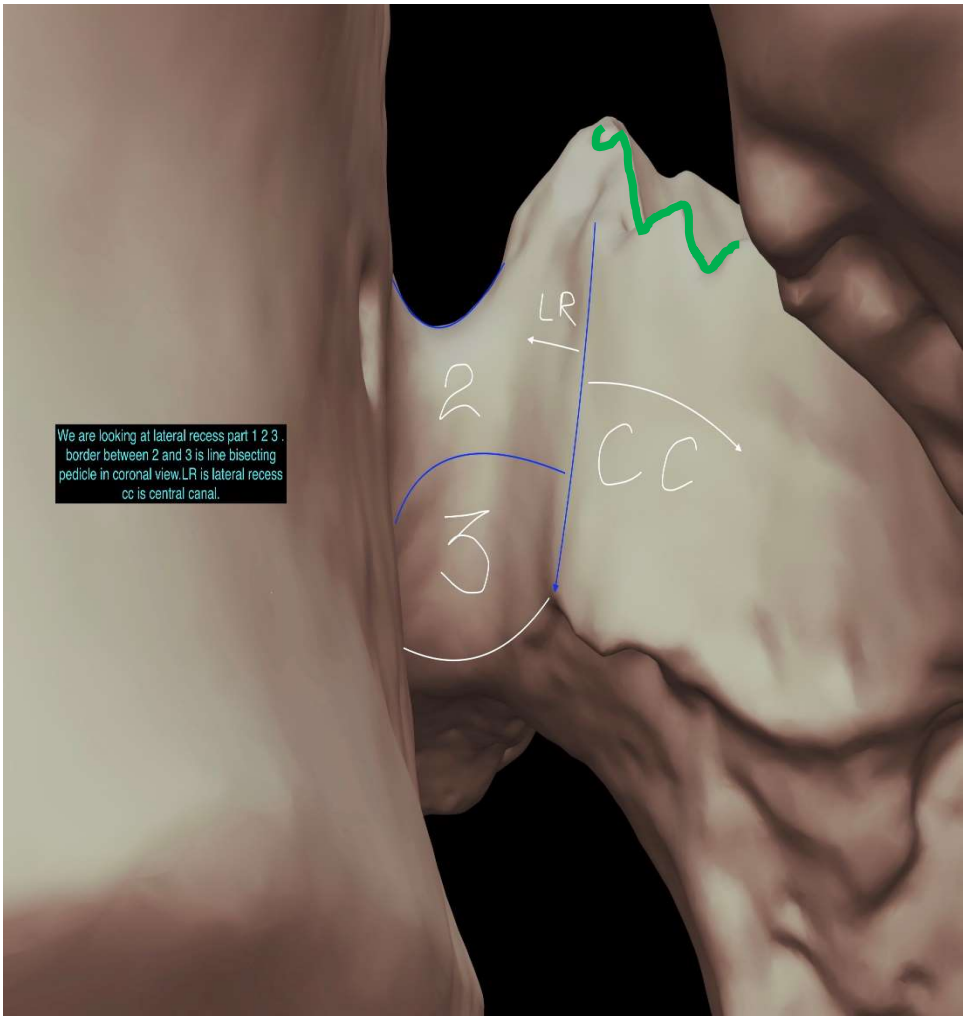
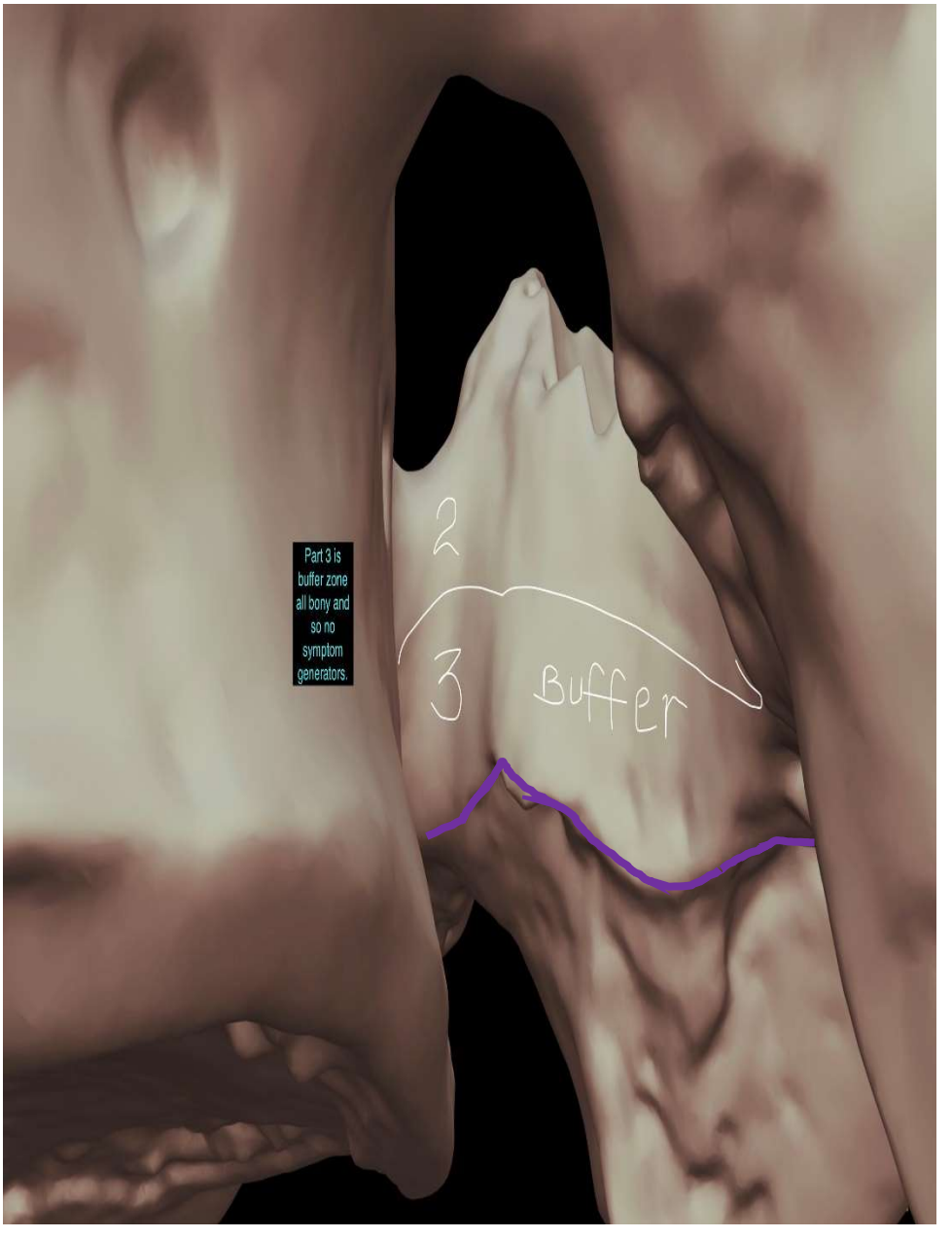


Image 6: Inner walls of right lateral recess or lower zone seen from left foramen.

Part 3 is from mid across pedicle lines to lower border of pedicles. This part is called buffer zone and continues with caudad upper zone. Posterior wall of lateral recess meets posterior wall of canal that is receding lamina at facet edge. [Blue straight arrow] Lateral recess itself in axial cuts can be curved like c or angled like < >.

This image also shows the lamina upper border shown in green that has lower attachment of ligamentum flavum on it. Ligamentum is NOT on its ventral or dorsal surface.

Image 7 Buffer zone of lateral recess.

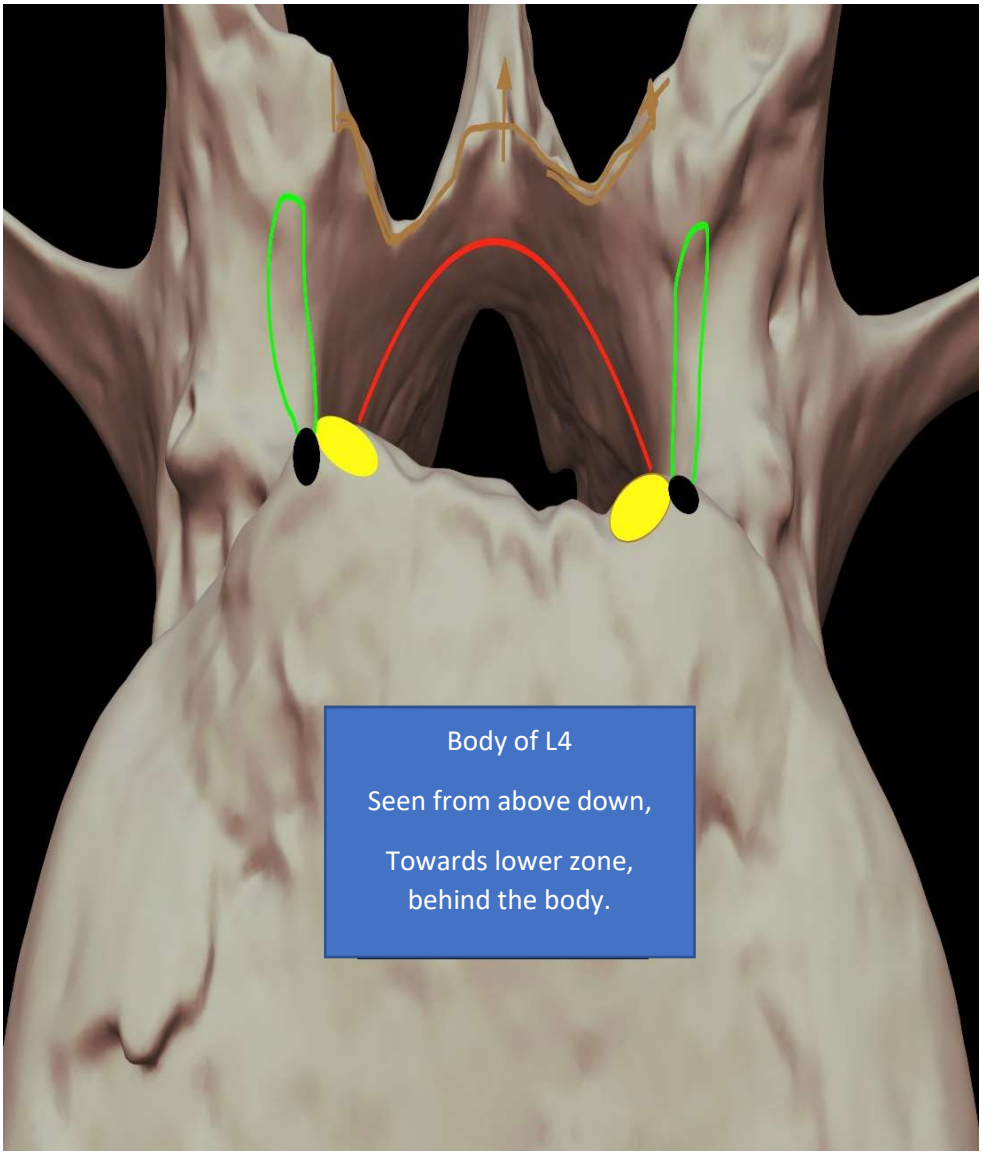


Part 3 or buffer zone has no symptom generators. Lower border of buffer zone violet line in image above, is in line with lower border of the pedicle. This area near lower pedicle border is sacred zone as it contains root, DRG and segmental artery.

Image 8 and 9 superior view of L4 and L5 body.

L5 has better lateral recess developed. Distance between facet edge and pedicle inner wall will decide width of the recess in axial cuts.

Image 10: Looking at lower zone behind body of L4.



Brown is ligament attachment to laminar edge.

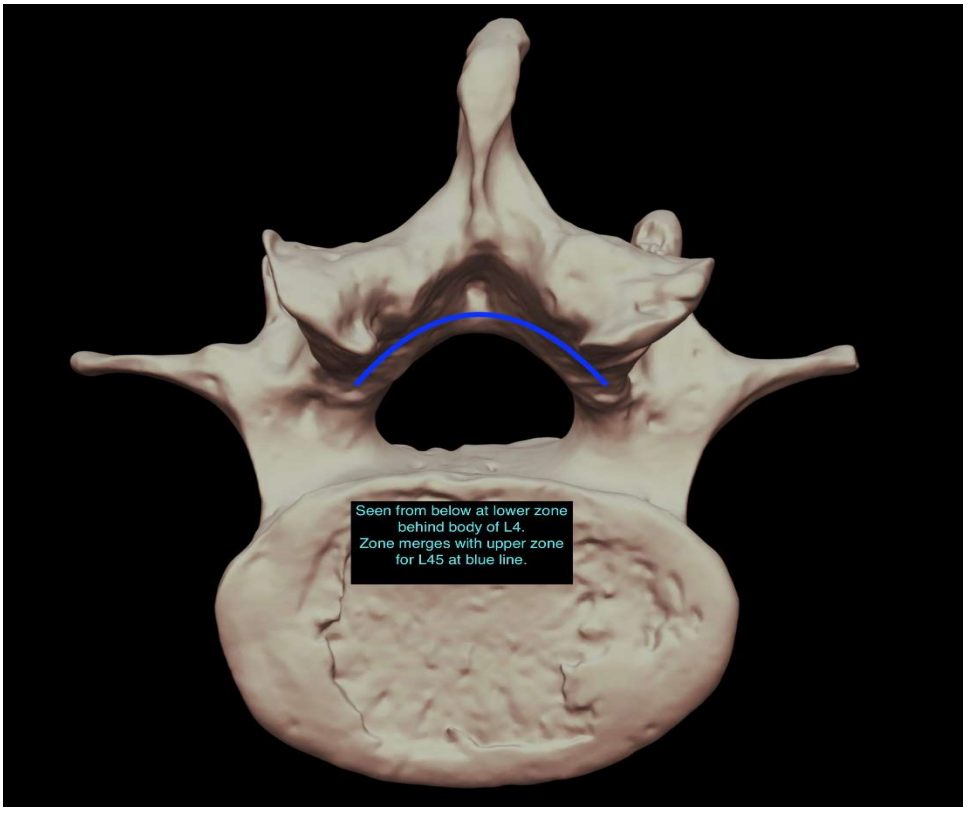
Red is border between part 2 and 3.

Yellow nerve path at entry in part 1.

Black is landing spots for transforaminal access.

Green denotes suprapedicular part 1 of lateral recess.

Image 11, 12: Looking at canal from below behind L4 and L5.



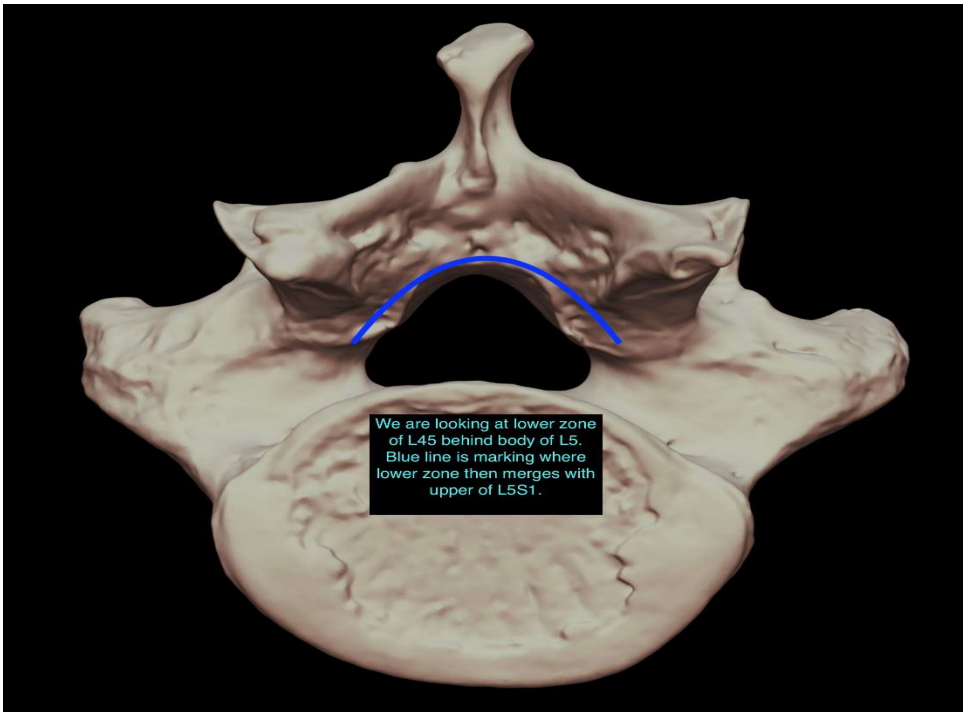
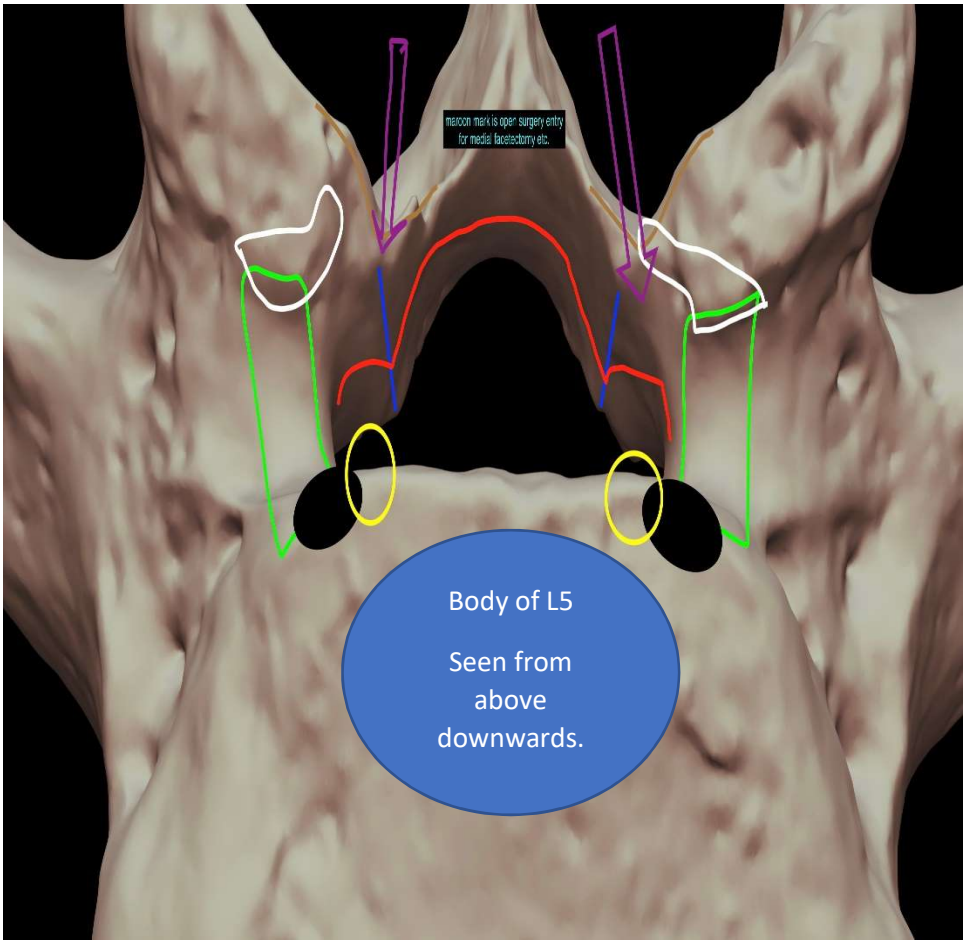


Image 13: Our landing in foramen for lower zone access black dot.

Target AREA IS WITHIN FEW MM FROM OUR FORAMINAL LANDING.



Green part 1 supra pedicular soft tissue lateral recess

Black landing spots for transforaminal surgery.

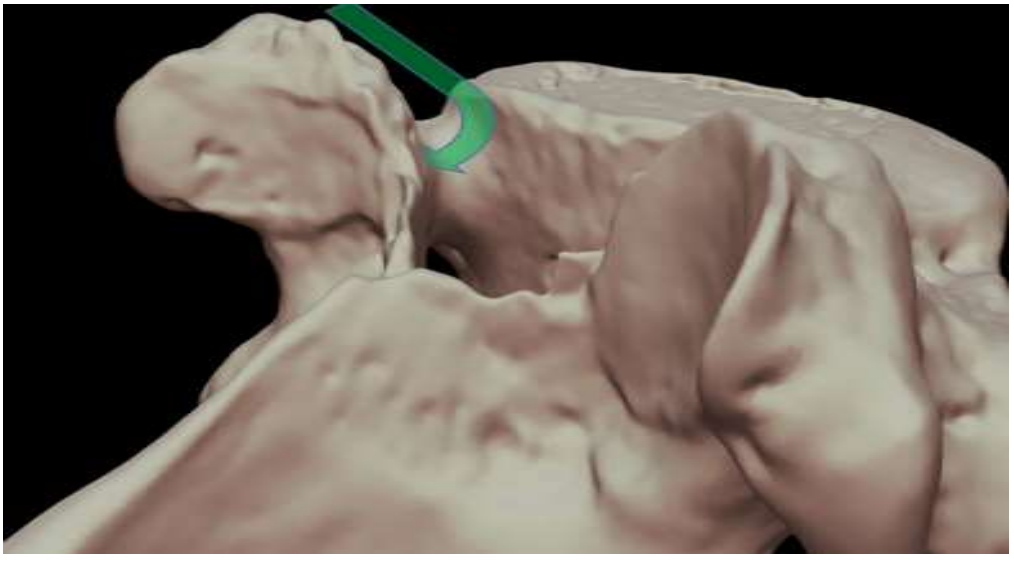
Yellow likely location of nerves entering root canal part 1.

Red border between part 2 and 3 of lateral bony recess.

Blue lines are edges we need to cross for lateral central canal.

Maroon arrows is where we do medial facetectomy in dorsal wall of part 2 lateral recess. White is subarticular NON articular portion SAP.

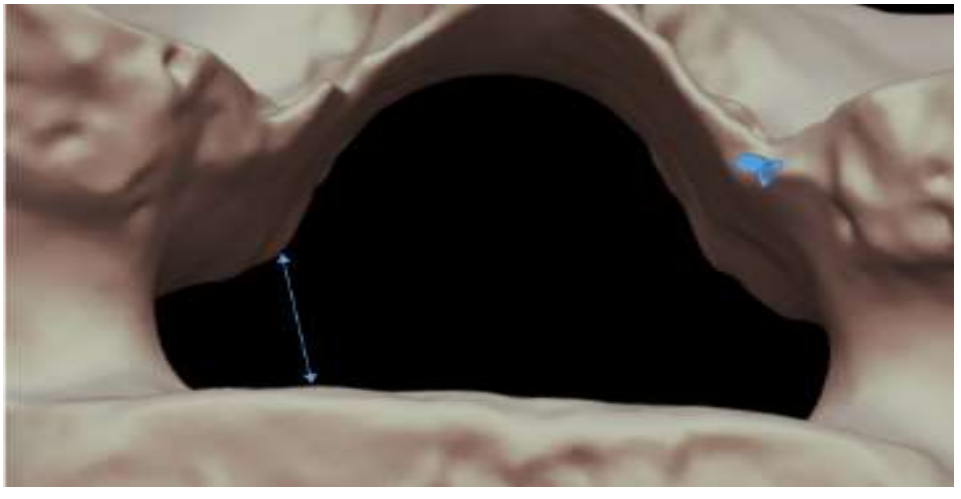
Image 14: Our strategy of going for roof of part 2.

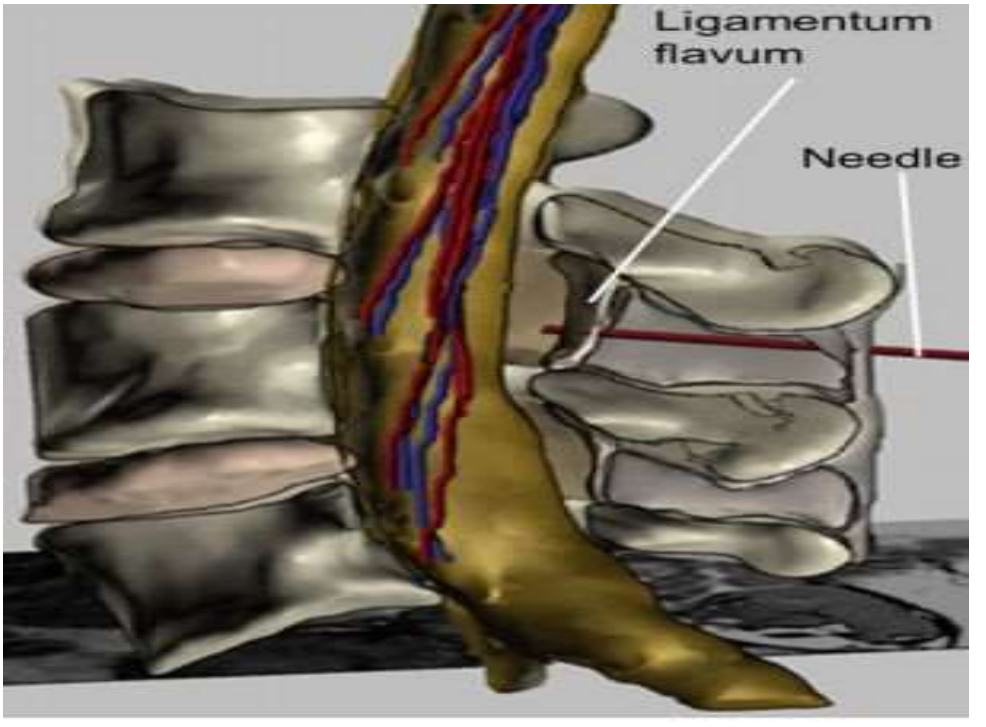


Lower zone entry, further path SHOWN IN LEFT LZ. Height of lateral recess seen at edge of facet. Edge is marked with blue dot. This is medial facet border, border between medial and lateral ligamentum flavum and central and lateral canal.

Image 15: Look at lower zone canal.

Specifically we look at stenosed lateral recess as root lies here. LRS is one root affection. Central canal is **not** part of symptomatic changes.





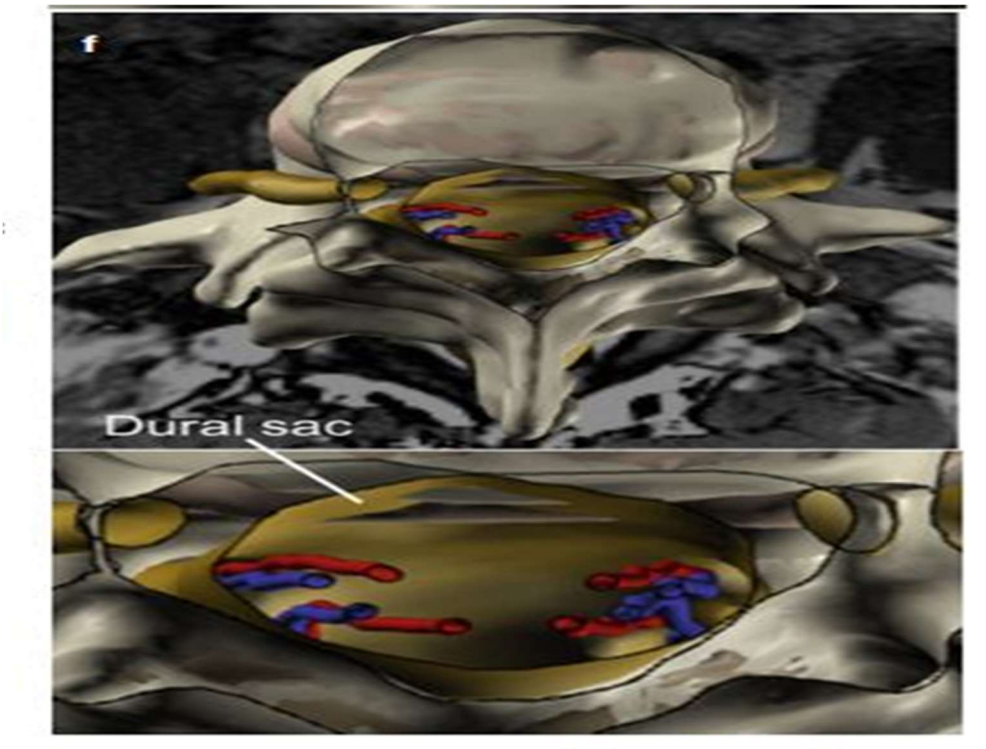


Image 16 17 18 intrathecal journey of roots. Sloping down from dorsal to ventral and stay in lateral part of the sac, immobile in root canals.

Epidural fat and veins: There is no retrodural fat pad at this level. Small amounts of epidural fat may be seen around emerging root sleeves if these have detached; as in the lower lumbar region. Epidural veins are present are visualised at this level as vertical channels. They may be covered by or be a part of peri dural membrane. Veins draining this part of canal join the ascending lumbar vein outside the foramen. Veins in this zone are valve less, part of batson's plexus and are the compressible part of the contents. They may cause sizable ooze during endoscopy or open surgery. The venous pressure though is low.

Soft tissue: Lateral recess may be very narrow. Ligamentum flavum generally is very thin or practically absent here. Except upper cephalad soft tissue posterior wall, rest of lateral and anterior walls are smooth bare bone in part 2. But root is relatively immobile at part 2 and 3.

Ligamentum flavum: Ligamentum flavum is attached edge of lower lamina in this zone. Ligament in medial part is away dorsally so not significant part of symptom causing change. In coronal plane ligamentum may be covering facet joint partially in its cephalad upper part only. Over emphasis on ligamentum flavum is unwarranted. IT IS IMP TO SEE LATERAL RECESS ROOF part 2 MAY NOT HAVE LF.

TARGETS:

Anterior T 6 [ventral]: in part 1

Lower disc margin osteophytes, down migrated disc herniations, Hard collagenised annulus near lower endplate of disc, Posterior annulus with loss of concavity more towards central part of canal, Old unresolved type 2 or 3 herniation adding to root entrapment.

Posterior T7 and T8 in part 2:

Sagittal or coronal Facet related hypertrophy at edge and changes related to ventral capsule, synovium, Synovial cyst formation at lower facet margin, Hypertrophy and synovial growth at lower pole in roof of lateral recess, Synovial growth transgressing covering ligamentum flavum [if present].IAP related changes ventrally inside canal and not in dorsal facet capsule.

Lateral: foraminal soft tissue in NOTCH part causing soft tissue lateral recess stenosis part 1, congenital narrow canal, and short pedicles.

In buffer zone [part 3] we have no symptom generators.

Coronal images to further refine understanding of LR and switch from open surgery to TFE.

Surgery in lateral recess and lower zone is sometimes fought with very narrow BONY walls. The lateral recess can be narrow and working in that tight area would need BONY foraminoplasty in lower foramen to arrive and land in lateral recess in transforaminal access. We work in lower notch of foramen after widening its walls enter recess proper at part 1.

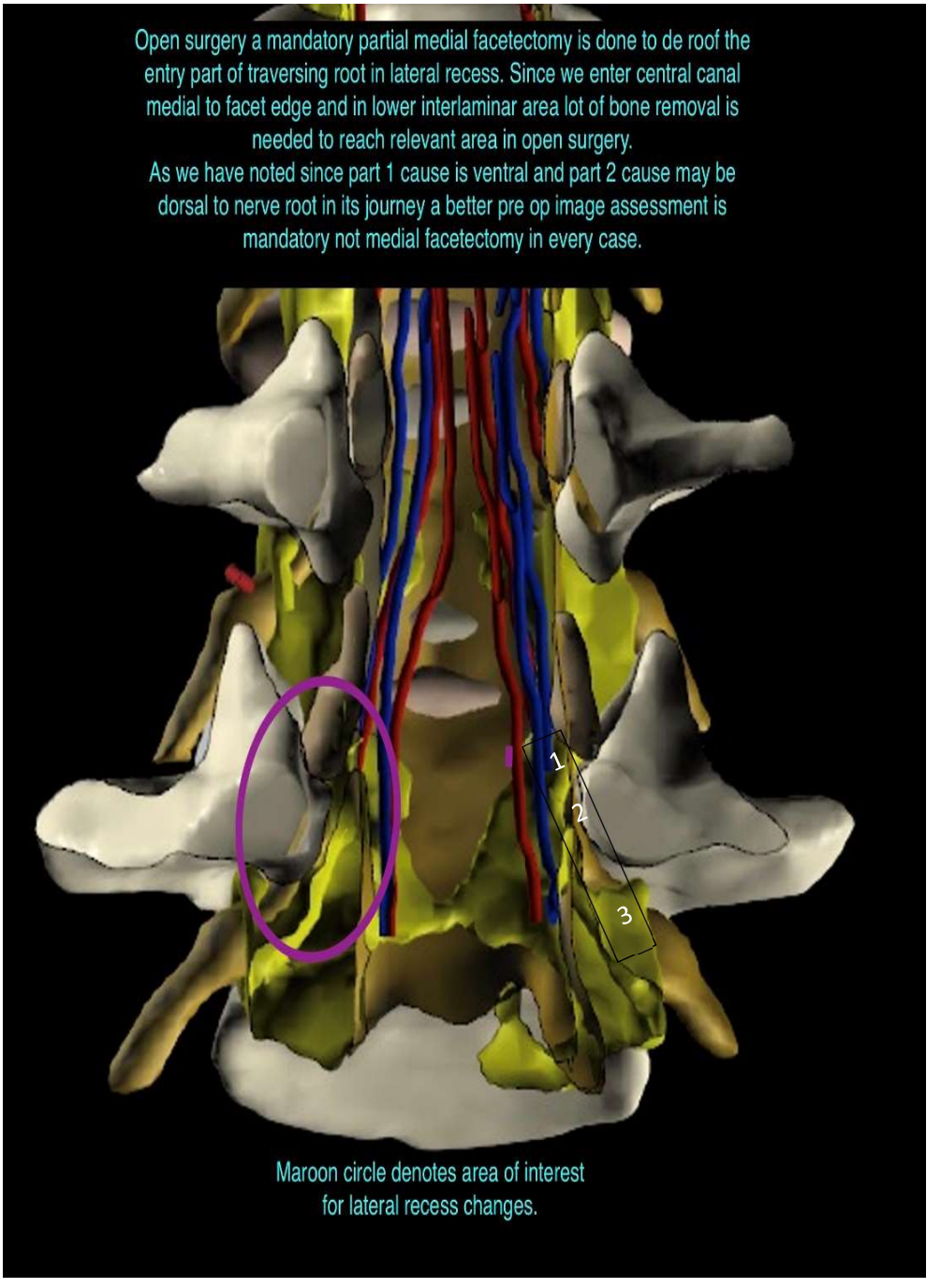
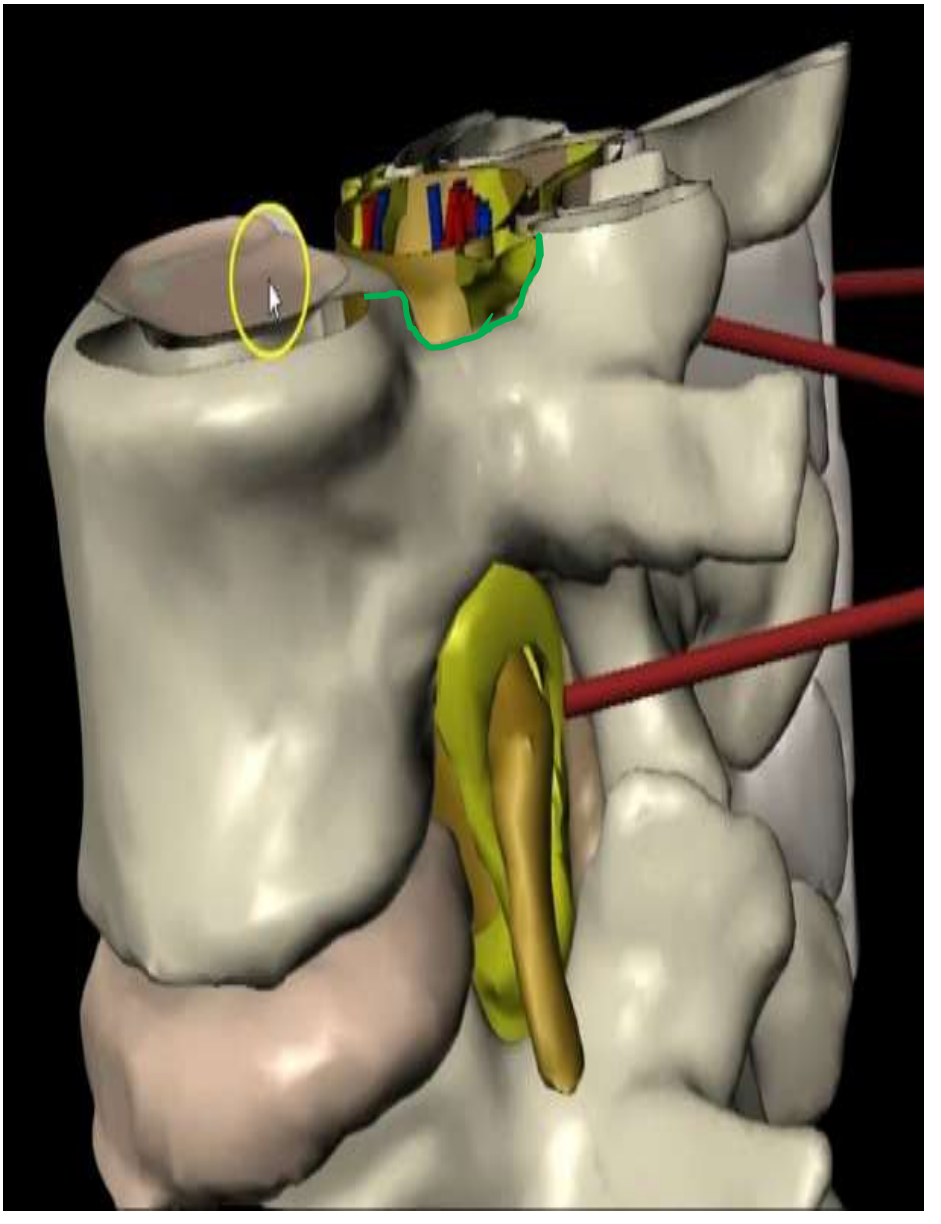


Image 19: Commonest intervention is needed on ventral and lateral to traversing root plane at its entry to root canal. Additional oblique pediculectomy from top of pedicle to mid across level during endoscopy may be adequate volume expansion for part 2.

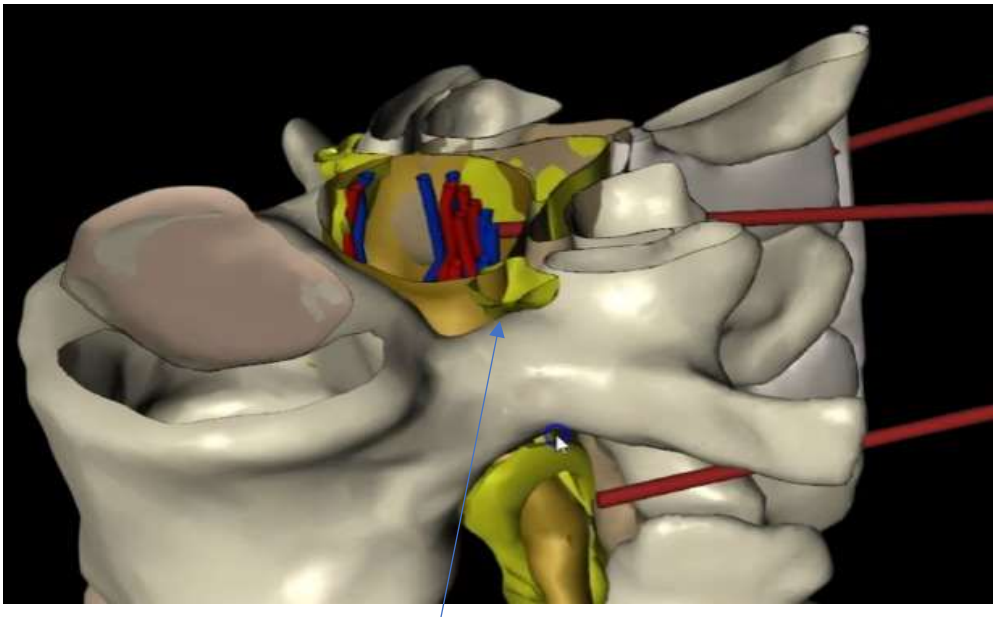
We will now see a 3 d images and sagittal build of lower zone to enhance our understanding before surgery.

Image 20 Sag section at lower end plate of disc going down.



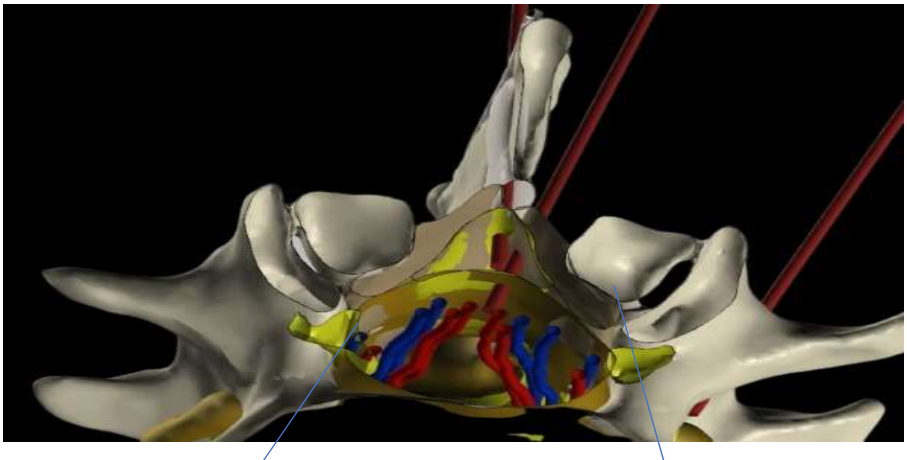
We can see notch of lower foramen in green , lower disc endplate and close traversing roots entering part 1 of the root canal in part 1 that is soft tissue lateral recess .

Image 21 Same section highest level of lower zone seen from above.



Lower notch at pedicle and Sap beginning. Important when working at lower zone part 1 root canal entry in soft tissue lateral recess. We are looking at axial perspective at same level. It shows the traversing nerve closer to lateral wall in recess.

Image 22: Axial cut at lower zone part 1 looking to part 2.



Axial cut shows relation of the facet edge in part 2 of root canal, to the traversing root that is closer to pedicle groove.

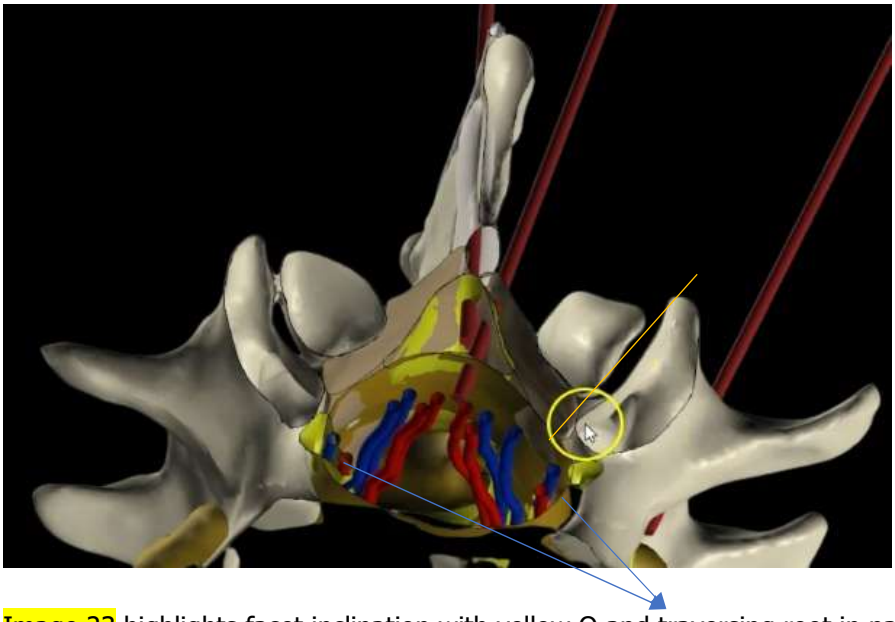


Image 23 highlights facet inclination with yellow O and traversing root in part 2.

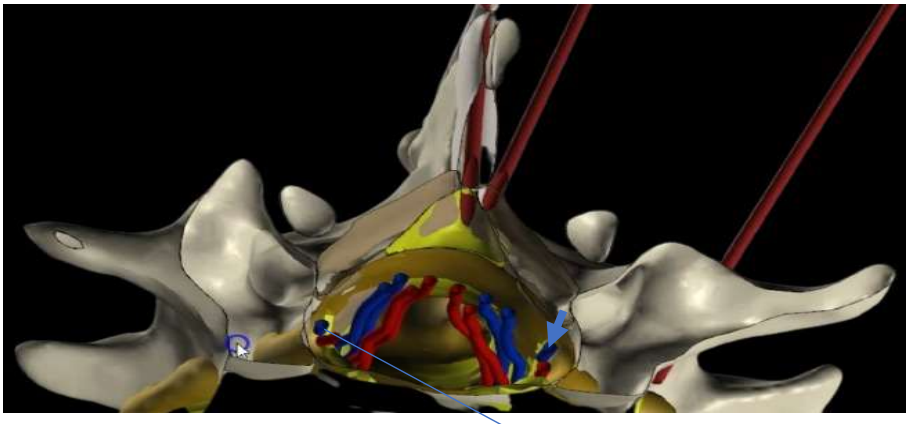
More about facet inclination: Table 1

	Male		Female	
L1	45.718	2.511	49.350	2.612
L2	27.013	0.497	30.645	0.599
L3	26.973	0.459	30.605	0.560
L4	33.479	0.470	37.111	0.571
L5	45.548	0.585	49.181	0.686

The superior facets show two main components—sagittal and coronal—sag a prominent feature of LI and L2 and coronal prominent in L4 and L5. Angles and depths of facets of the lumbar spine are least variable at L3 and L4 and most variable in the two transitional regions, LI and L5. If facets are asymmetrical, asymmetry exceeds 20°; the intervertebral disc on more coronal side may get early degenerative changes.

We can see other roots of cauda equina that are floating in sac. We are sequentially going down and can now see ligamentum flavum coming in view at inter laminar area towards its insertion on edge of lamina.

Image 24: Part 2 of lateral recess.



If LR is tall posterior facet wall is much away from roots in part 2.

On left of image we can see exiting part under transparent pedicle [Blue circle] Ventral face of facet lower pole seems bare of ligamentum flavum small blue arrow.

Image 25: Traversing root entering part 2/3 of LR.

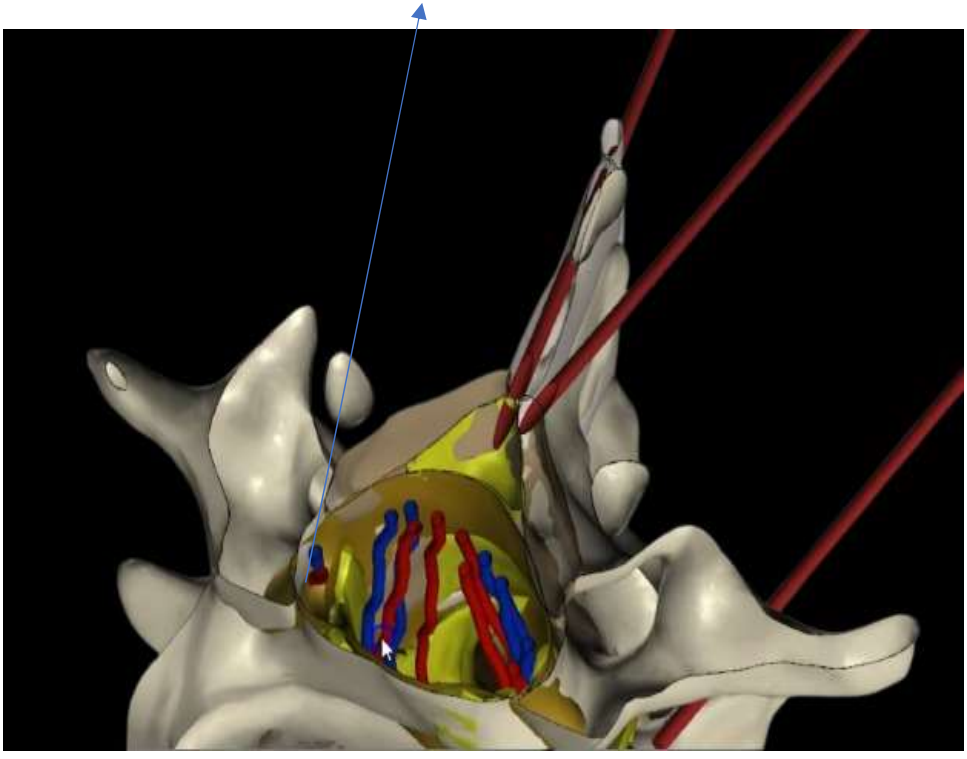


Image 26: 3 D cut for lower border of part 2. Onwards to 3.

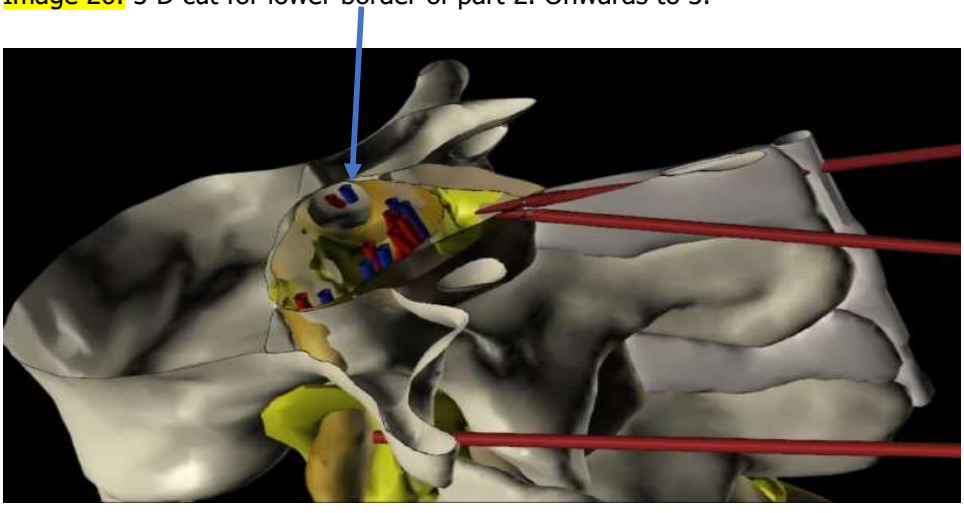
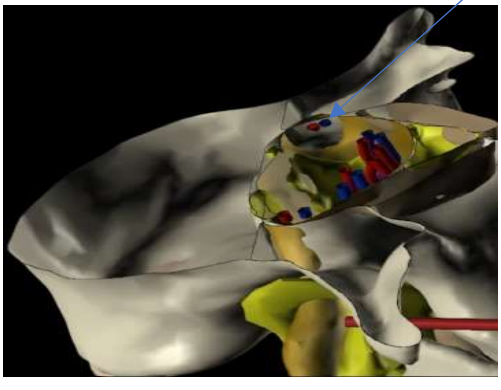
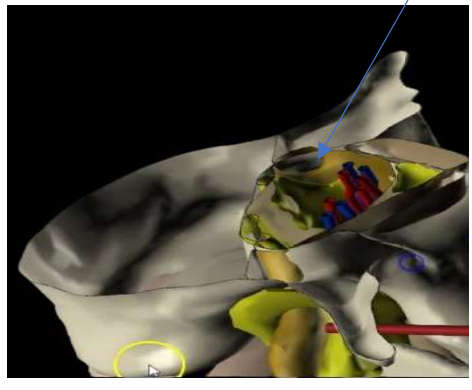


Image 27: 3 D cut showing opp. side roots in part 3, Image 28: 3 D cut opp. Roots exited





This area can be commonly accessed by medial facetectomy.

We can see traversing nerve closer to ventral canal wall and lateral pedicle wall soon to enter buffer zone and exit. Relatively fixed here. Same level with more oblique posterior view in image 28. Level of medial facet removal for exposing traversing nerve. The cuts are not exactly parallel to disc end plates, but upwards oblique so we will be seeing little more post wall. These sections make it clear that medial facetectomy may be needed only if ligamentum flavum is present and hypertrophied in part 2 dorsal wall, not in all patients.

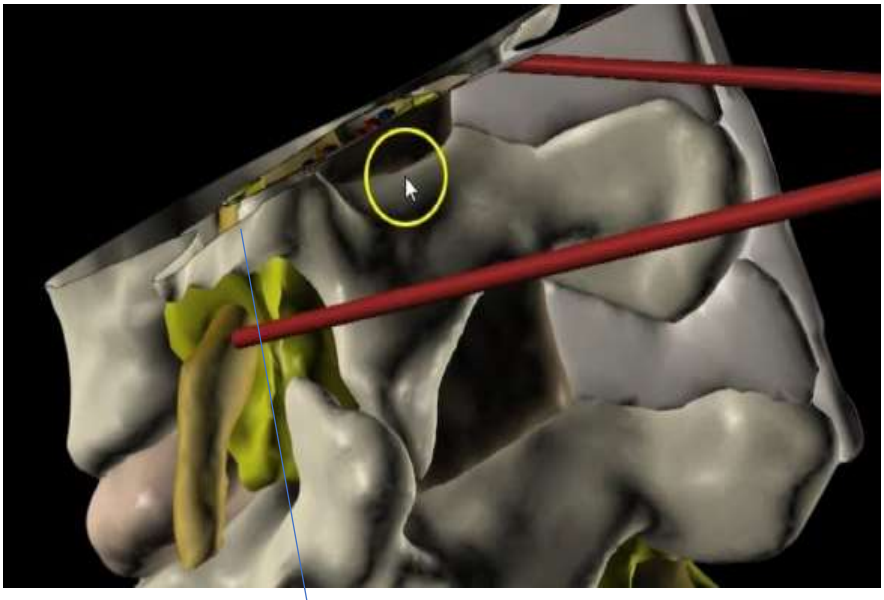
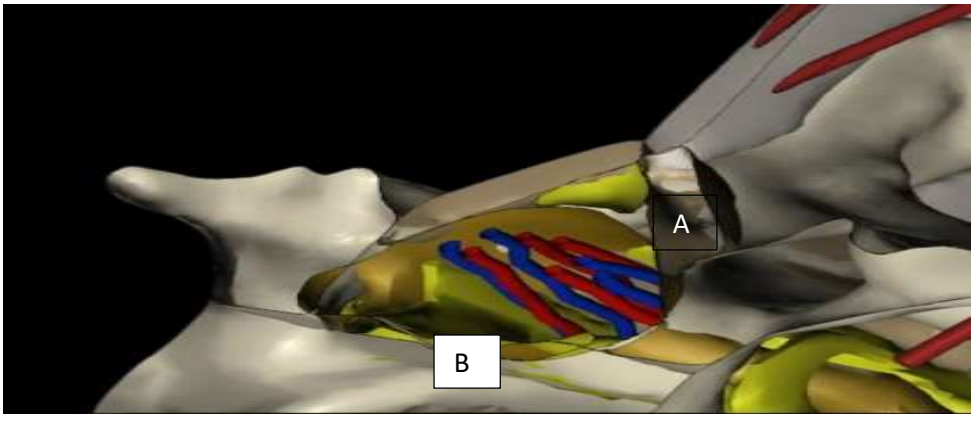


Image 29, 30: 3 d image to see traversing root in part 1, 2 LR.

We need to note relation of dorsal canal wall and the thecal sac contents. Traversing root is extra thecal and closer to ventral wall, in root canal. The pedicle is transparent in this section. Doing a mandatory medial facetectomy for a relatively immobile root here may not be relevant in majority.



Area A of medial facet removal, B our tfe access landing. A & B are recess height apart, Access A is more morbid and under GA.

SURGERY IN LOWER ZONE for ventral T6 or dorsal targets T7, 8

Dealing with lateral recess or lower zone we may have multiple valid questions. How does transforaminal solution for lower zone stenosis compare with open midline posterior surgery done by medial facetectomy? Can soft tissue changes in walls be treated with ventral scraping alone without removal of bone in first part of the lower zone? Is direct 270^0 decompression possible by going dorsal to traversing root without harming nerve root? Can pedicle wall in its part 2 be removed to add to lateral wall decompression? [Shown as red area over pedicle in image 5 above] How do we confirm adequacy of intervention? Is it possible to do all this under vision in surgery under local anaesthesia and stitch less access? IS peridural membrane relevant to lower zone stenosis?

Variables in lower zone lateral recess

As a preoperative analysis we need to see following variables to be certain that our transforaminal approach will address the issue at hand completely. In relation to root and its path level where Root is leaving thecal sac, Relation of root to ventral and dorsal wall in upper and middle 1,2 part of lateral recess that may not change with supine or prone position of patient in MRI images, Root along pedicle groove part 3 does not change with supine or prone.

We need to assess Depth of axilla [how far cephalad it is] in coronal plane and soft tissue in axilla previously described as cone on top of SAP; commonest cause of failed open surgery in upper zone, SAP tip in upper zone, Laminar angle at midline posterior even though lamina slopes away, if laminar angle is acute it contributes to stenosis.

We also need to know Facet inclination sagittal coronal and tropism. In lateral recess AP bony dimensions is equal to pedicle length. In congenital stenosis the pedicle height may be short and give symptoms with subsequent degeneration.

We also see and note Lateral recess at anterior upper part with soft tissue degenerate lower annulus in part 1 T6 and Posterior wall facet changes with lower pole cyst etc. in part 2 T7 Presence of synovial facet cysts etc.T8. Ligamentum flavum across facet joint and over lower pole of facet joint needs to be visualized to confirm its presence over lower pole.

Transforaminal access and surgery is helpful and better in lower zone in comorbid and aged patients. Since we have a refined clarity on anatomy and we are aware of the inherent variations we have a dynamic plan to address the symptom generators here. In open surgery; PLAN is same for all patients, where we do laminotomy and medial facetectomy to expose traversing nerve and decompress its roof. In transforaminal access we target ventral, lateral and dorsal wall of recess part 1 and 2 that is a 270^0 decompression of root canal.

Traditional surgery is still unclear about anatomy, dimensions and symptom generators in roof and floor and lateral wall of [in axial cut a C shaped or < > shaped] lateral recess. It is known however that root is closer and immobile with ventral and lateral wall at this root canal entry area part 1 and lower down in part 2 very close to lateral wall that is pedicle groove. Root is travelling down and outwards, in upper zone also it is "fixed" by foraminal ligaments and not floating.

Traditional surgery has been highlighting ease of access to lateral recess contents by posterior midline interlaminar roof access by medial facetectomy then breaking the unyielding bony rings. There is no clear guideline about amount of facet bone to be removed and many times it lands in breaking or total removal of an articular part of facet and add to instability.

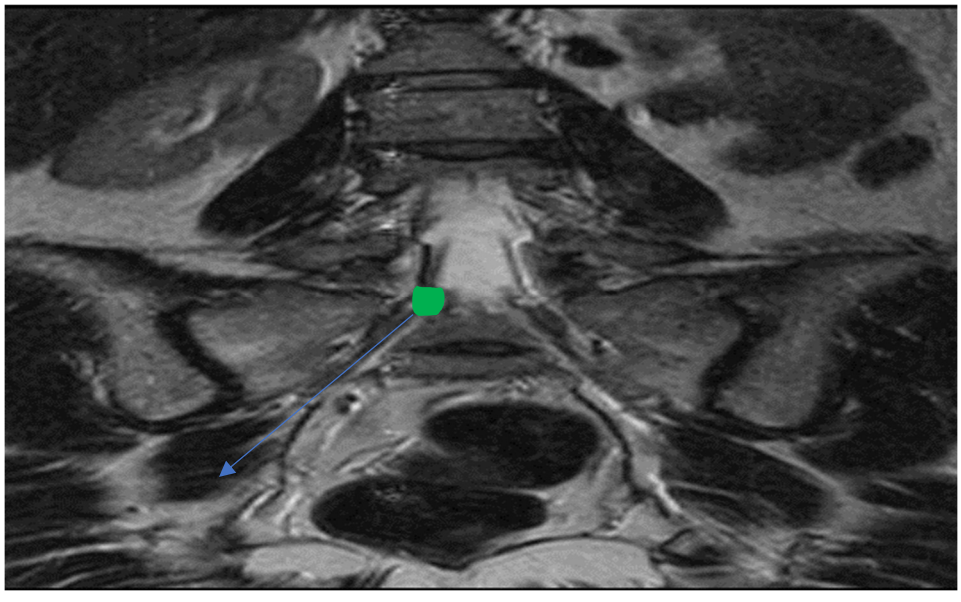
Degenerative changes and ineffective remodelling of facet joint make partially removed facet too weak to bear any load. This can happen more commonly with osteoporotic spine. In scoliosis and rotational deformities of the posterior elements of the vertebrae and degenerative changes in facet joints and its ventral face may compress dura and roots. Part facet removal may result in instability. Accessing floor of the lateral recess is impossible in open surgery unless more and more of facet is sacrificed to go lateral to the traversing nerve at entry to root canal.

The root is fixed to ventral and lateral wall by peridural membrane and other likely "ligaments" and is sensitive due to pathophysiological changes that generate symptoms. It is important to NOTE that we can NOT mobilise the "fixed" to ventral wall nerve but decompressing it from exterior compressive force by a hands off approach. In traditional only dorsal wall is decompressed, in transforaminal all 270 degree decompression can be achieved.

If we look at bony dimensions we are touching posterior bony wall at part 1 itself as it is ~ 8 mm. But our access angle needs change if we target roof. Here if needed we separate the landing point in lower foramen to an extraforaminal anchor fulcrum to raise working instrument tip towards roof. [Details in appendix II about TEKU]

The nerve changes its course in sagittal plane from being dorsal inside dural sac at L45 level intrathecally to ventral at root entry. In coronal image it looks almost as an uninterrupted straight line from conus to toes but it is immobile and fixed at root canal parts 2 and 3 green dot.

Image 31: Root travels in a straight line in coronal plane and is fixed in root canal.



Walls of the recess are smooth except at entry part 1 and posterior wall part 2. When disc is collapsed IAP may go down and may abut in lateral recess at roof part 2 [UNPROVEN]. Anatomical relation between FACET lower pole and root needs better imaging studies in NORMAL and diseased spines and analysis of all previously mentioned variables.

Transforaminal and posterior midline interlaminar access give entirely different view during surgery of lower zone. In open interlaminar access surgery we see IAP and its medial face from behind to start with. It is excised to cut upper bony ring and expose SAP and traversing nerve ventral AND LATERAL to it. What is the exact relation of edge of facet to traversing nerve needs good imaging and preoperative study.

Surgery for the lower zone and lateral recess:

Access to all walls of lateral recess:

1. Access is landing at mid lower pedicle in AP x-ray image and at lower endplate of disc or on ventral facet in lateral.
2. We can always start more cephalad and pointing towards lateral recess and lower zone. As seen with blue arrow. Here Transverse process NATURAL fulcrum or teku can be used. Image below
3. Open: Coming from posterior midline and doing medial facet removal can only land us on the thecal sac and NOT anywhere near root in canal.
4. Working ventral to root on the end plate and act on disc changes, soft tissue lateral recess and osteophytes part 1. Lower notch widening is essential for access to LR canal, dorsal wall.

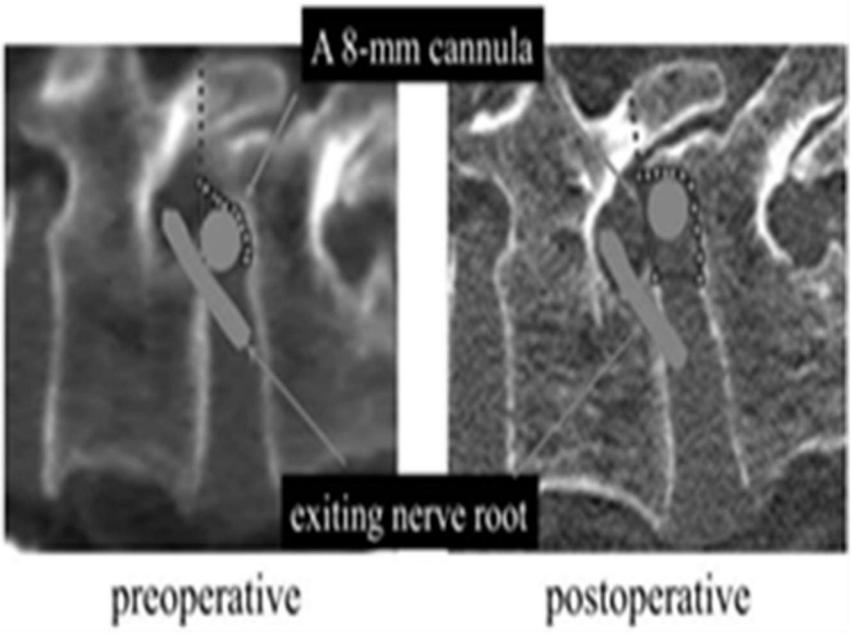


Image 32: Lower notch or part 1 LR is enlarged by bony burr.

Image 33, 34: We land in foramen in mid pedicle line pointing towards lower zone part 2. Use of TP fulcrum can be of help for part 2.

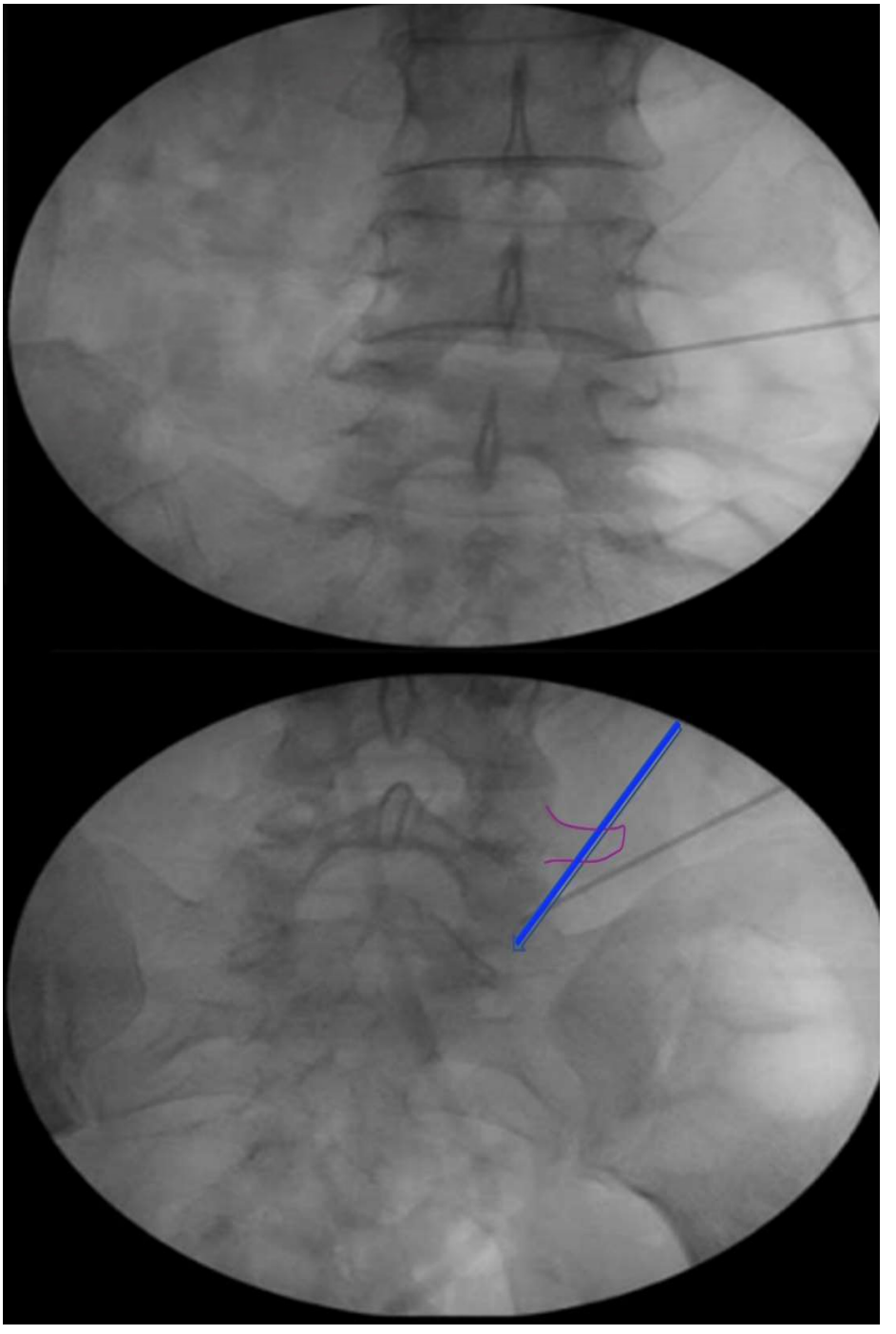
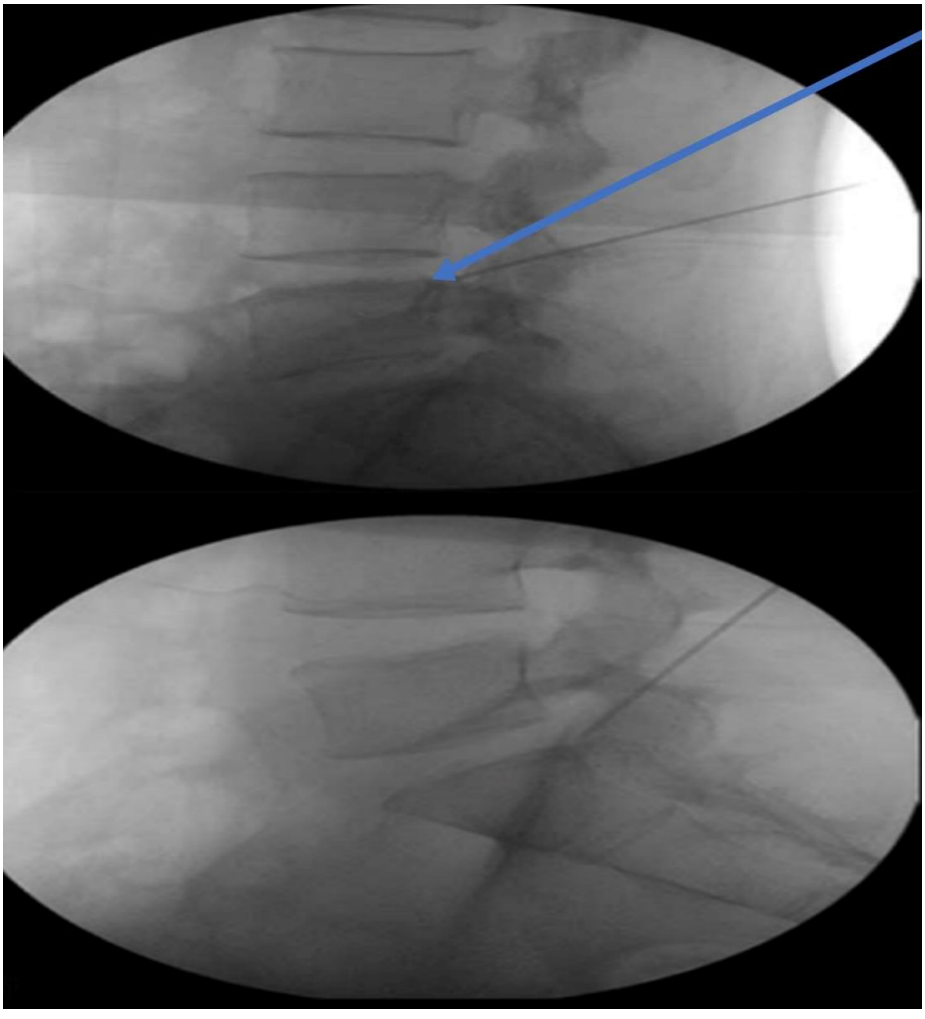
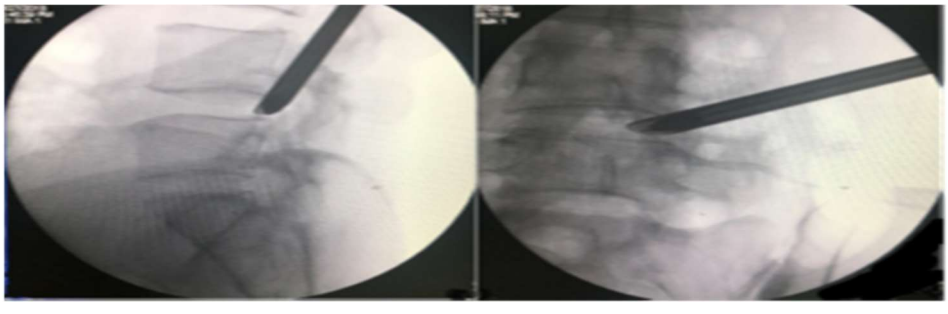


Image 35, 36: landing as seen in lateral images part 1.



Part 2 target is dorsal wall so we need to change trajectory towards roof.

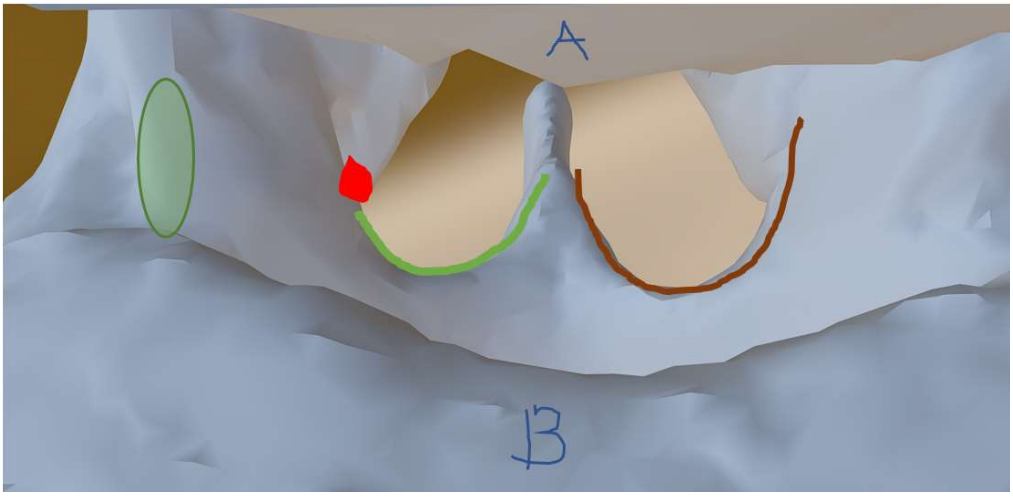
Images 37 A B Show position of working instruments during surgery part 1



The area dorsal to root or under surface of SAP and lower pole of IAP will have soft tissue cover including facet capsule and a leash of veins this is ahead of landing point and much dorsal and deeper [medial]. IAP is always dorsal to SAP in a 45^0 inclined joint. So we may not come face to face with joint line during endoscopy.

Image 38: ventral perspective of lower zone part 2.

Seen from front thru disc, behind body: red dot lower pole: green line upper edge of lamina, with brown ligamentum flavum attachment on edge of lamina. Ligamentum flavum is contiguous, but facet capsule or synovial cysts can be separate isolated tissues. Additional imaging confirmation for facet related tissue is possible with arthrogram. Body above and below A B. Area marked with green round is part 1.



Haemostasis at surgery of lower zone:

Traversing root is surrounded by leash of veins that come out of foramen and join ascending lumbar vein. They are known to ooze a lot during either endoscopic surgery. In endoscopy working under saline irrigation and with bipolar RF or plasma cautery helps in haemostasis.

Illustrative case 1:

F 32 with central down migrated herniation but with claudication on left. Finer analysis of images in recess shows a central disc herniation as anterior cause and facet capsular asymmetry on left narrowing recess on left. Since ventral decompression at soft tissue recess could get root vessels filled full and pulsation back, it was enough in this patient.

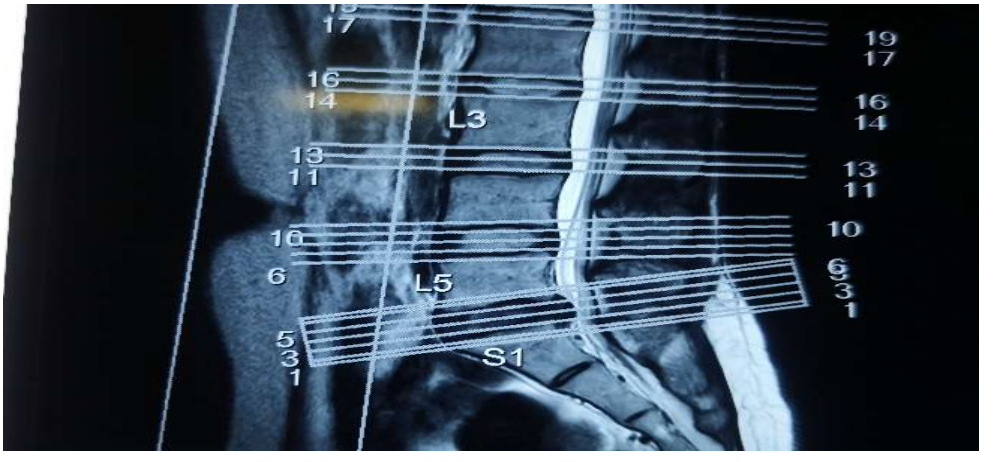


Image 39/1: Sag image with markings for the disc axial cuts.

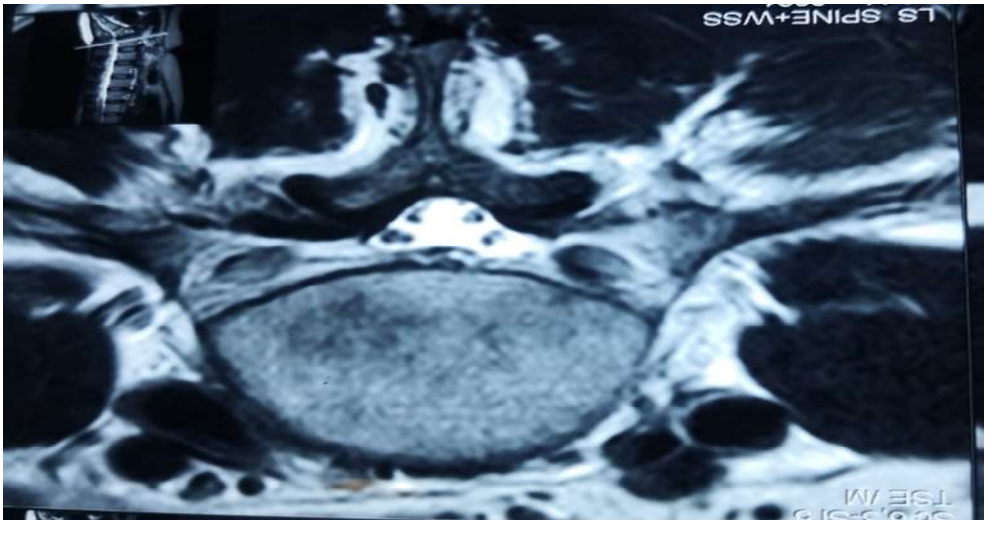


Image 39/2: Axial cuts planning for L5S1.

Start of axial cut. No abnormality. DRG in open foramina, confirms upper zone cut.

Image 39/3: Loss of posterior concavity of disc c. Middle zone cut.

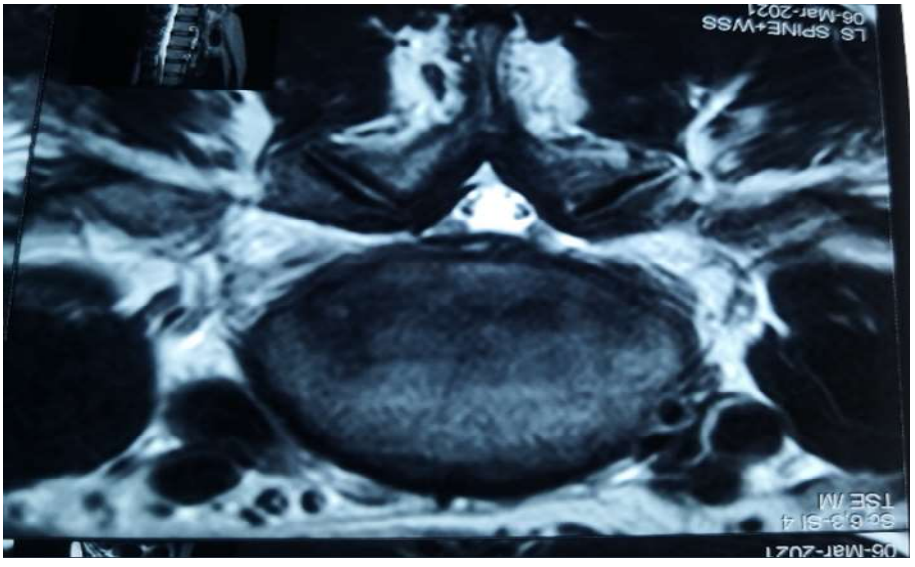
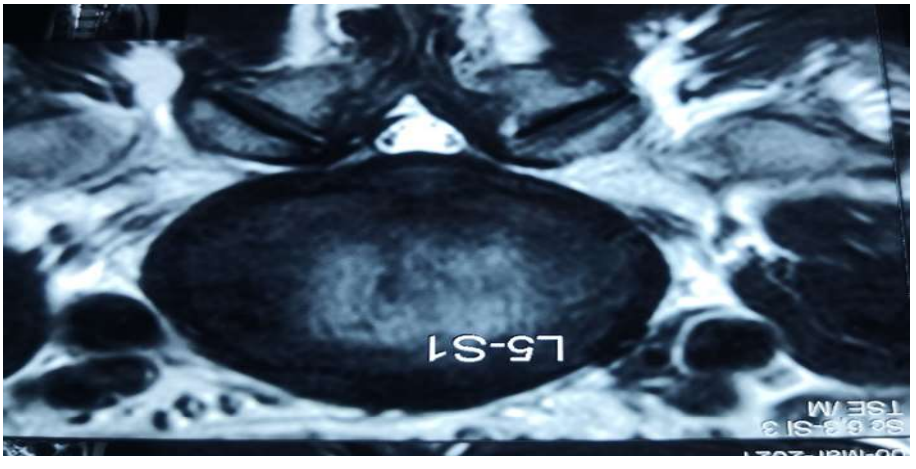
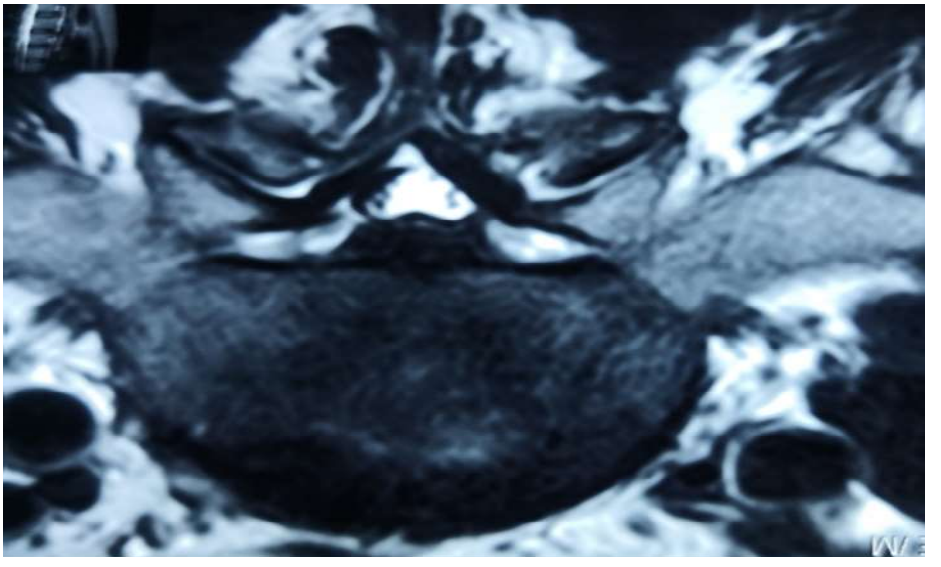


Image 39/4: Next caudal cut. Central sub ligamentous annular bulge noted. Narrowing of central canal noted.

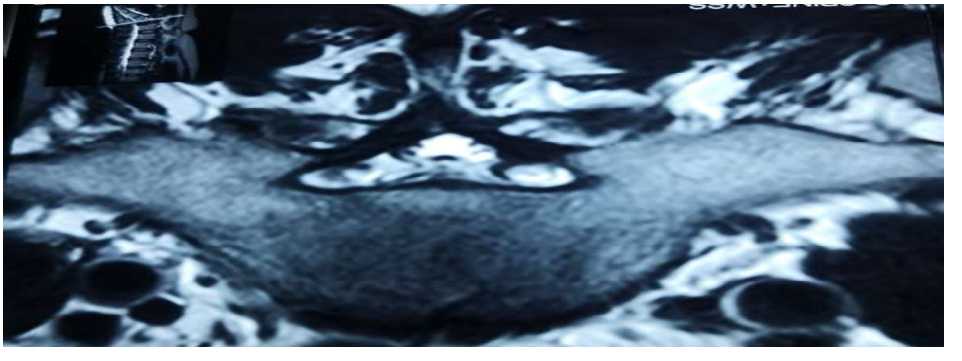


Above cut in beginning of mid zone. Facet joint seen, no micro instability. Central posterior annular tear and loss of concavity. Encroachment on canal. Intra discal entry under annulus is more logical than posterior midline where a high chance of dural injury likely here as herniation is close to posterior wall.

Image 39/5, 6: cuts at lower zone show a down migrated disc central and sub ligamentous.

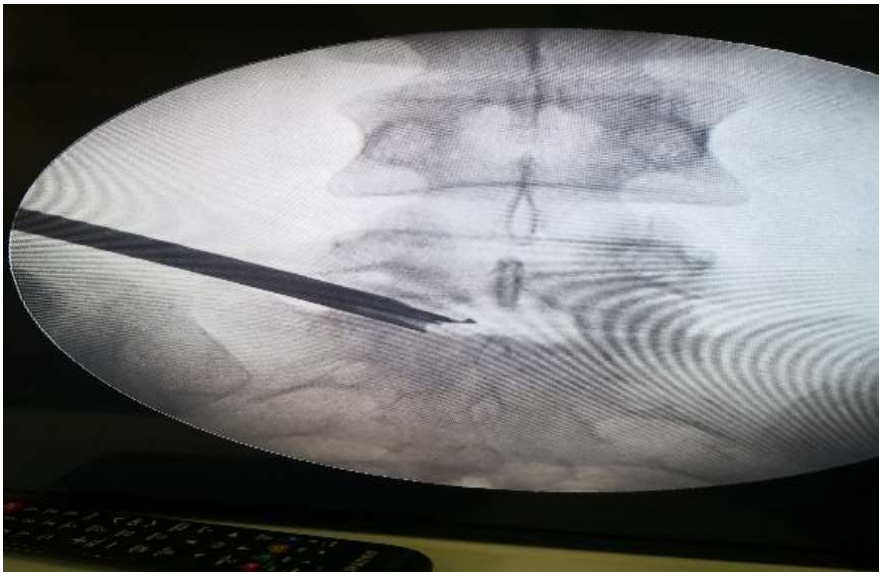


We see disc herniation and changes towards LR left. In image next tail of the disc fragment is seen, with left LR changes.



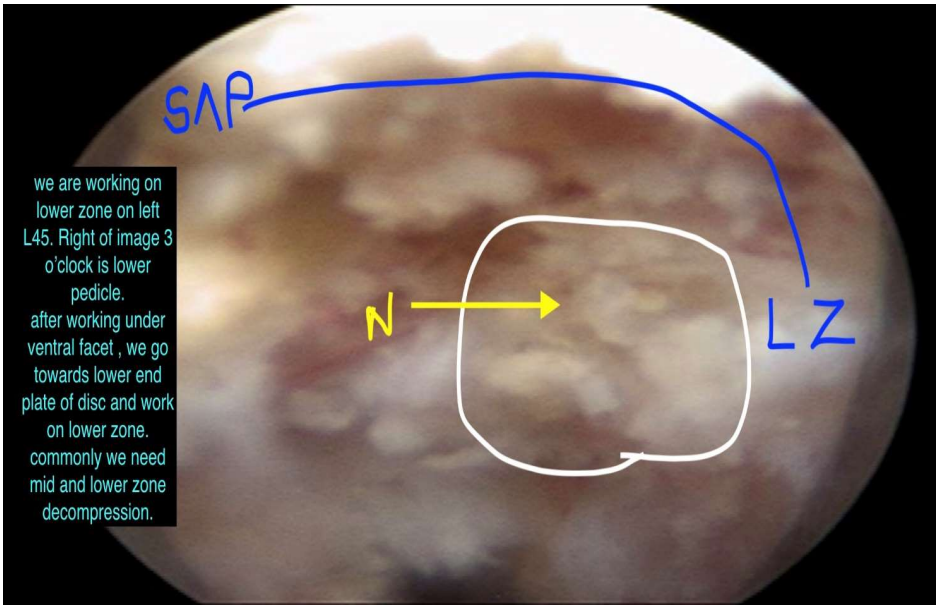
Surgical plan staying closer to lower end plate and then going over it after finding central annular tear for the migrated fragment.

IMAGE 40 A: X-ray 1 shows use of hook to stay close to lower end plate and tease the fragment. Image 40 B: X-ray 2 shows grasper in tear removal of fragment done. Closer and below lower end plate. L5S1 being lordotic working closer to lower zone is seen in oblique plane.




LIH
ROTN: 340
AVG: 04
X-RAY OFF

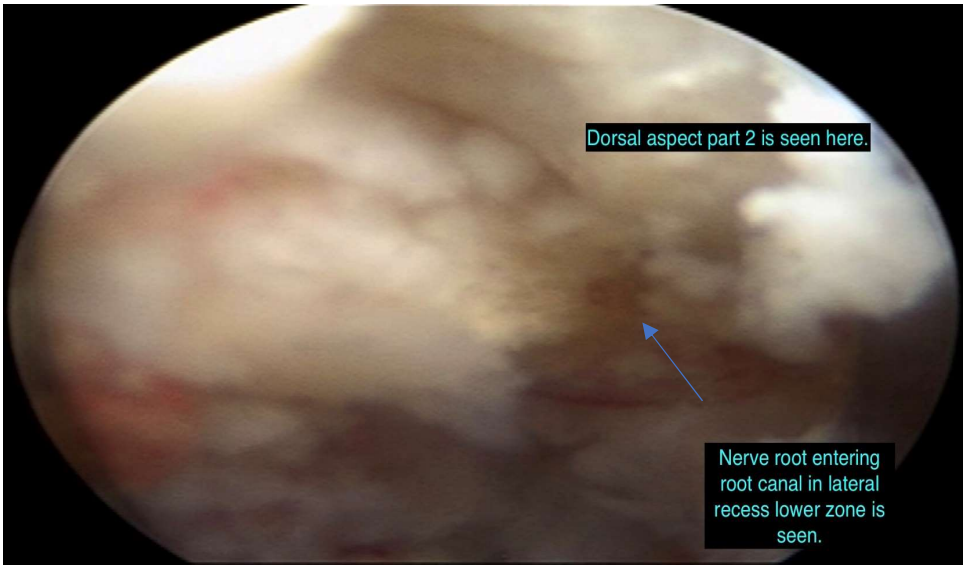
Image 41: Endoscopic view of lower zone part 1.



Right wall is endplate of the L5. We are at L45 decompressing lower zone at soft tissue lateral recess.

Pic next shows view on foraminal retreat, lower notch coming in view. We also see soft tissue occluding foramen.

Image 42: Endoscopic view on retreat in foramen. 3 o'clock is LZ.



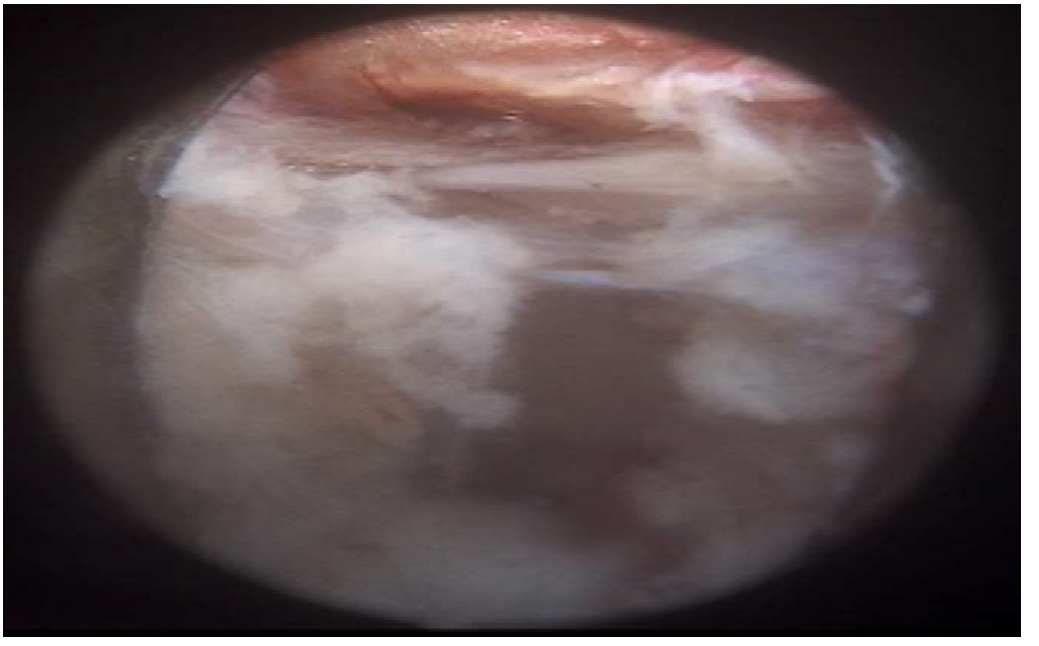
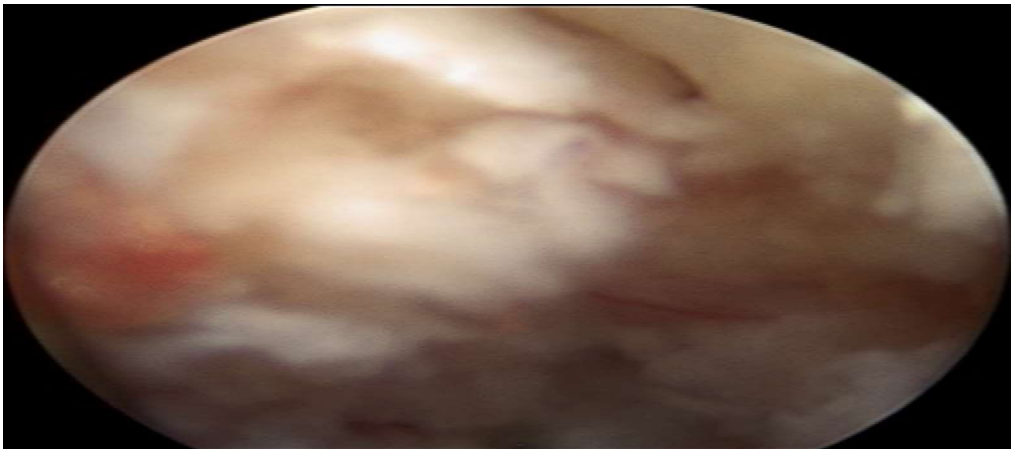


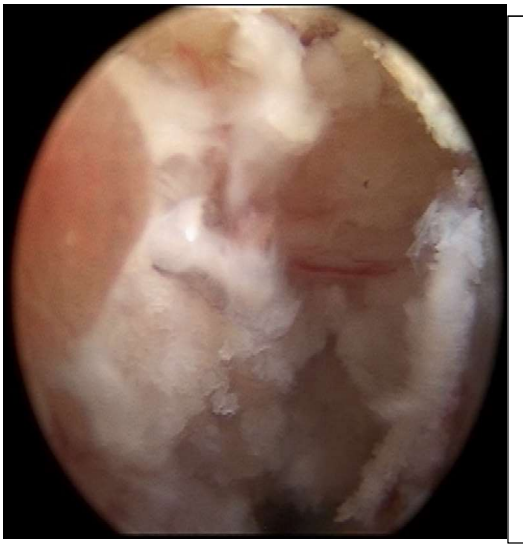
Image 43: Endoscopic view, epidural tissue above thin annulus. Intra discal view of annulus. Right is leg side.

Image 44: Intra discal view towards lower end plate L5S1.

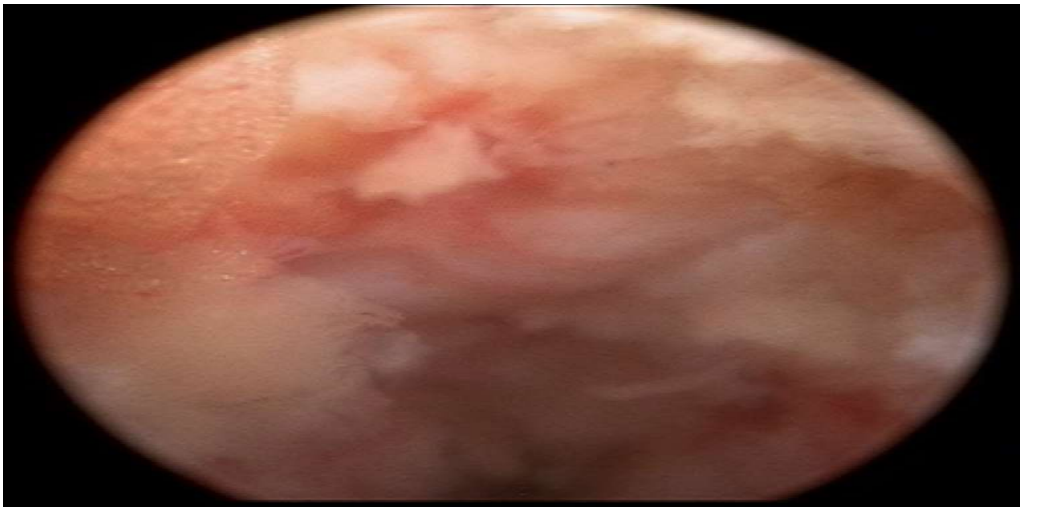
Intra discal view of the annulus and lower endplate and margin of end plate and epidural fat above end plate margin. Fragment removal at central lower annular tear. Nerve filled up well. Dorsal decompression was not needed.

Images 45: 1 2 3. Ventral decompression of root in LR.





1. Above lower notch part 1 view.
2. Left is nerve pulsating with its vessels seen confirming decompression closer to lower endplate at disc!
3. A view that includes mid zone disc decompression. Nerve seen at entry to root canal part 1 and was not sensitive at end of decompression.



The angle at which we approach the lower foramen and then under surface of the lamina, in absence of TP teku tech fulcrum; it sometimes needs Bendable instruments like flexible RF probes or Side firing Laser, articulated burr, bendable curettes and rigid trephine used for bone work. Since scope is 25-30 degree the work can be under vision. Patient being awake and aware makes it safe. Oversized burrs can also be used by "retro" use. The surgeon end of the burr is introduced back through scope before using it at patient end during surgery under vision. This can easily overcome limitation of "working channel size" of the scope as we may have stem of the burr of 3.5 but working end up to 6 mm. This is used to over drill lower foraminal notch to make it 8mm or adequate for our cannula. If we pre op assessment suggests need for roof decompression we do it.

Two tests of adequacy of decompression: [per HENRY CROCK]

1. Nerve root at entry to root canal part 1 loses its extreme pre op sensitivity to touching tested during awake aware transforaminal endoscopic surgery.

2. The dramatic rapid refilling of the perineural veins on surface of the exposed nerve root indicates adequacy of surgical decompression. In endoscopy it clarifies that if vessels refill, there is no further need of posterior or dorsal compression.

Illustrative case 2 Anterior causes in middle and lower zone part 1.

This is mainly image analysis study. IMAGE set 46 1-6.

M 63 back pain and claudication. In this patient the narrowing of the canal around traversing root is due to anteriorly disc changes and marginal osteophytes. We can clearly see that posterior wall of canal here has no relation to symptom generation and open surgery in this case would be unnecessarily destroying the posterior wall of lower bony ring just as a part of access. Image [total 6 images]

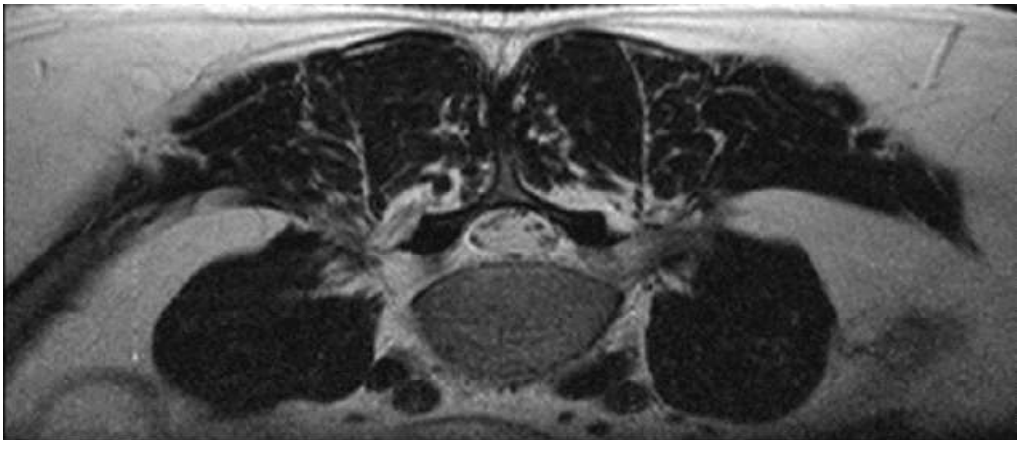


Image 46/1: Upper zone image 1 open foramina.

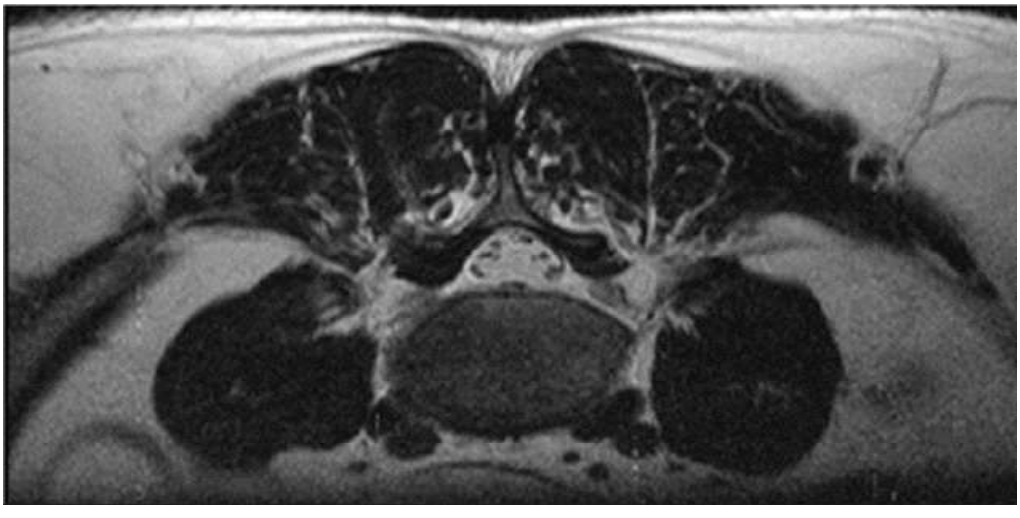


Image 46/2: Upper zone 2 DRG in foramina.

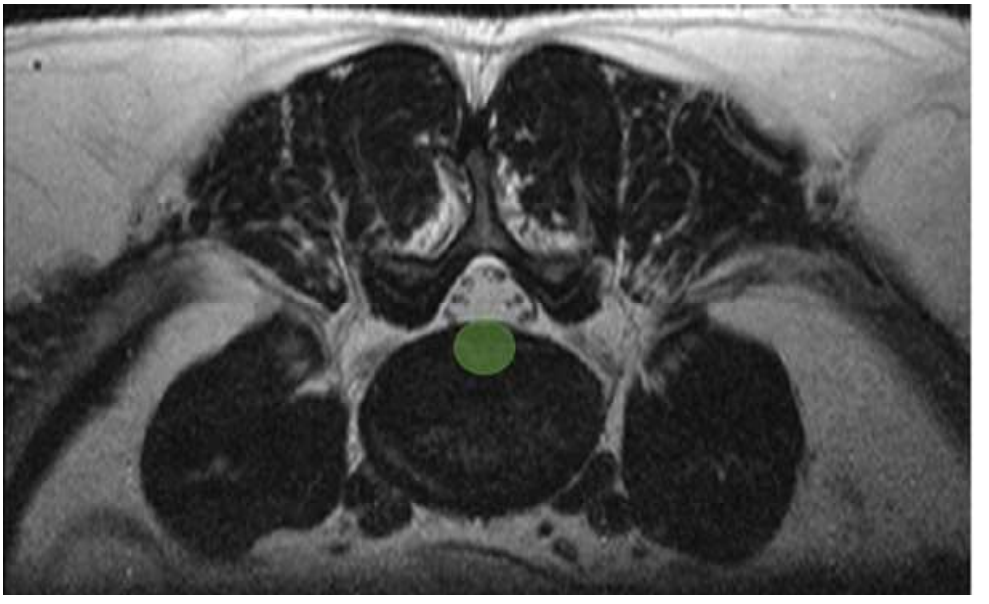
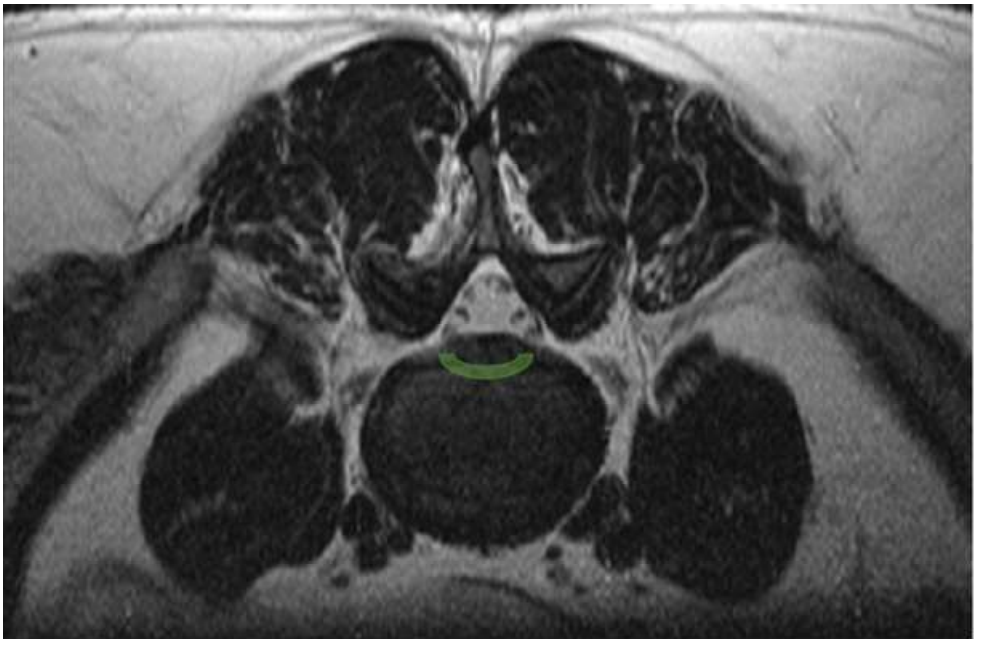


Image 46/3: Middle zone cut, normal root arrangement in dural sac. Loss of posterior disc concavity seen.

Image 46/4: Further caudal middle zone cut.



Facet at 45 degrees, roots normal inside sac. Green arc marks fragment that needs attention. No changes in facet margins or ligamentum flavum seen.

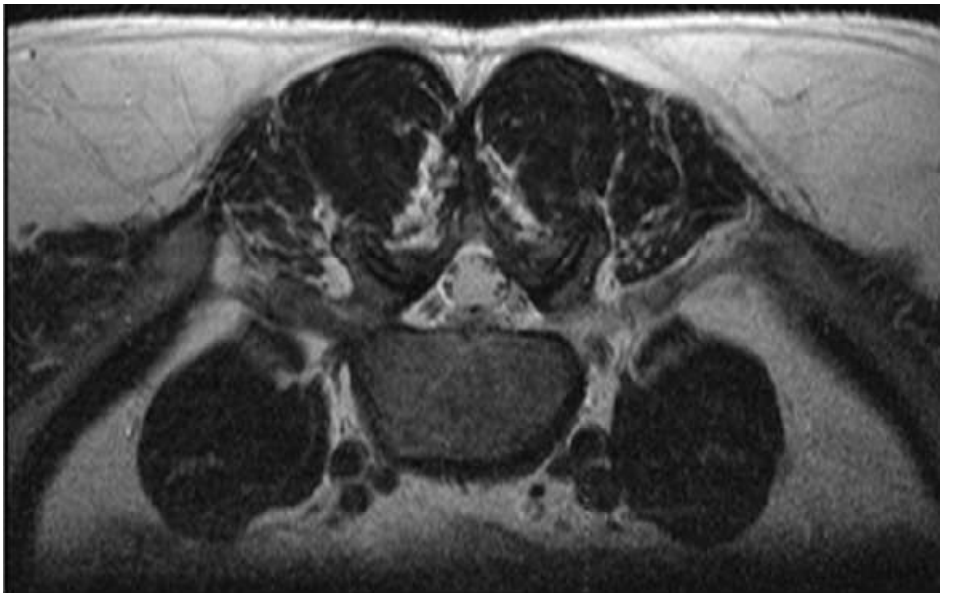
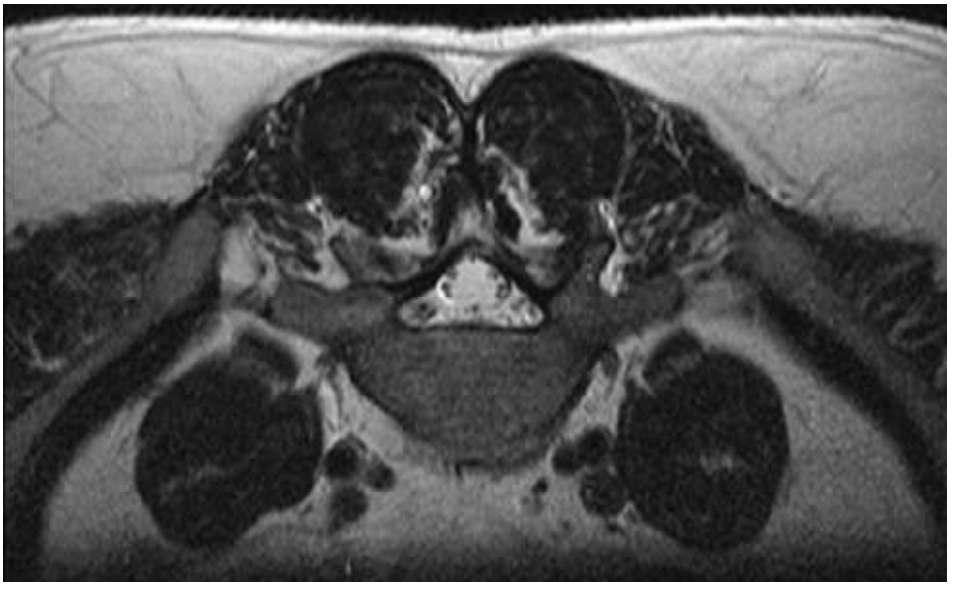


Image 46/5, 6: Central soft fragment under dural sac seen, dural sac and root arrangements ok except some change on left symptomatic side. Image next shows a normal lateral recess. Facet joints normal. Ligamentum flavum is normal. This can be said to be T 6 case.



Illustrative case 3: Posterior cause in lower zone canal wall part 2.

Traversing root is affected. Here cause is at facet edge and transforaminal access for channel plasty on roof of lower zone is very precise solution under local anaesthesia. Image set [total 8 images] with added markings on facet edge to highlight posterior part 2 cause.

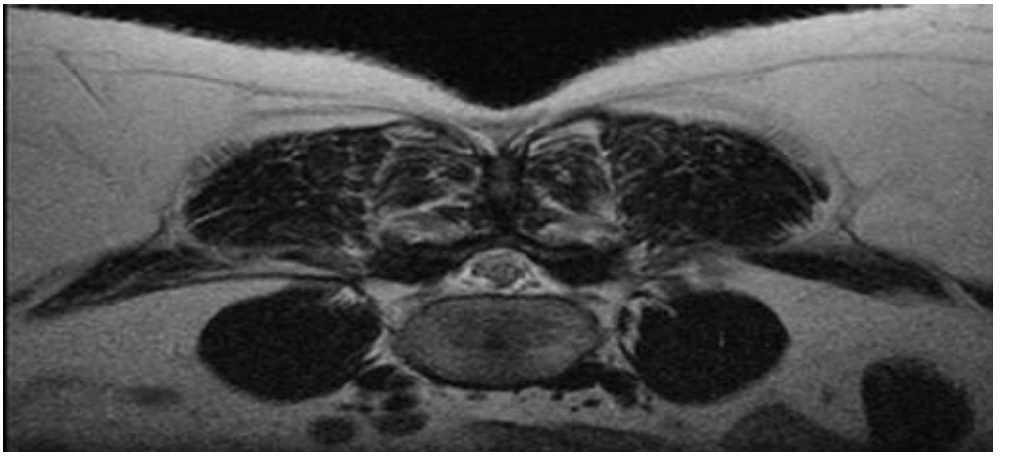
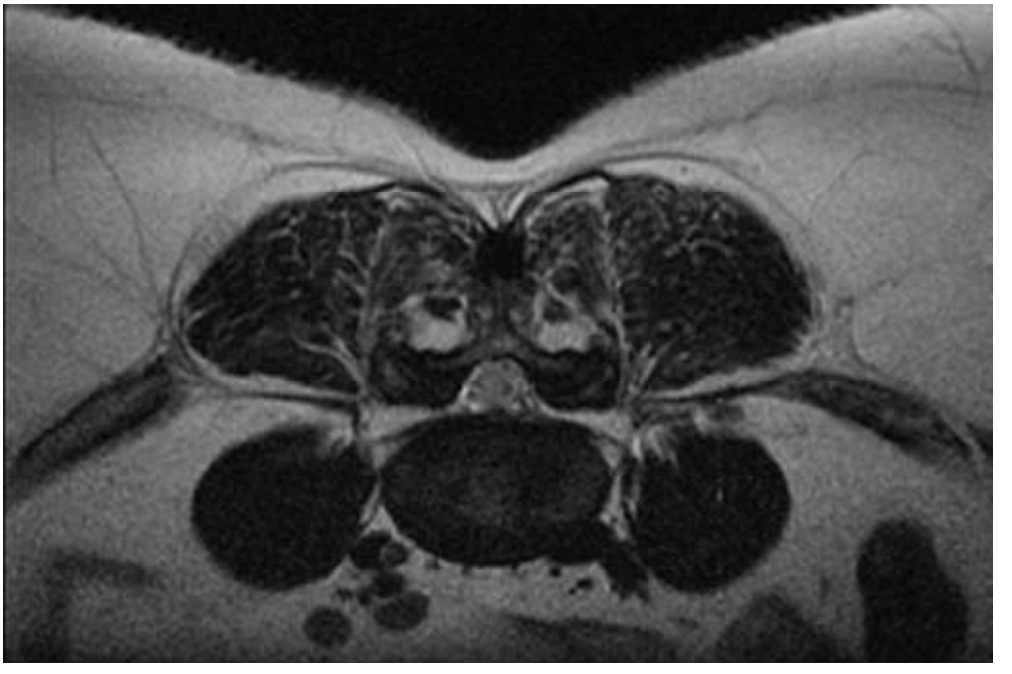


Image 47/1, 2. Normal upper zone and middle zone cuts



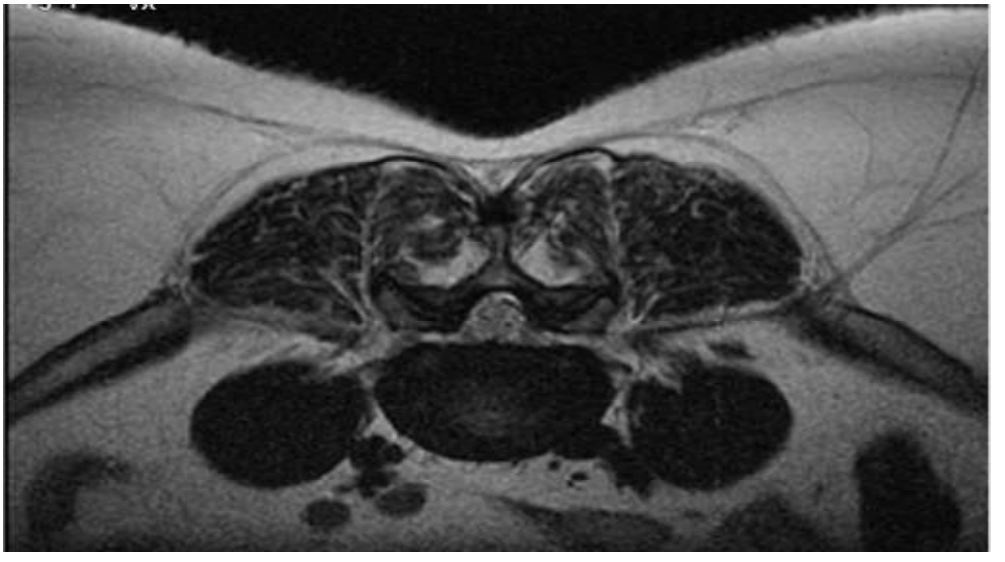
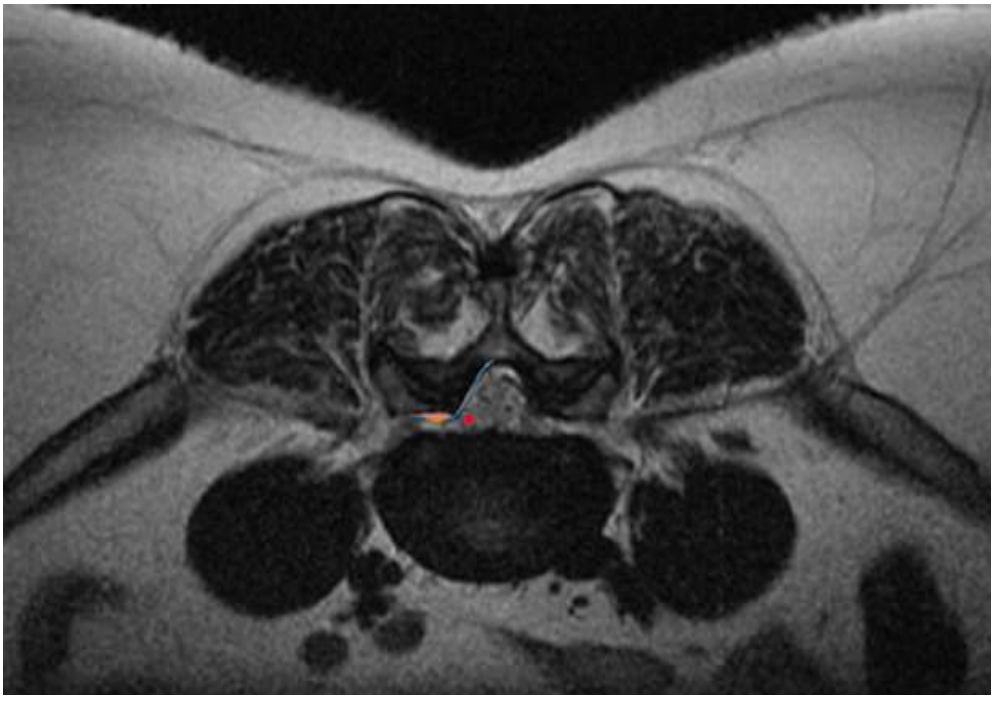
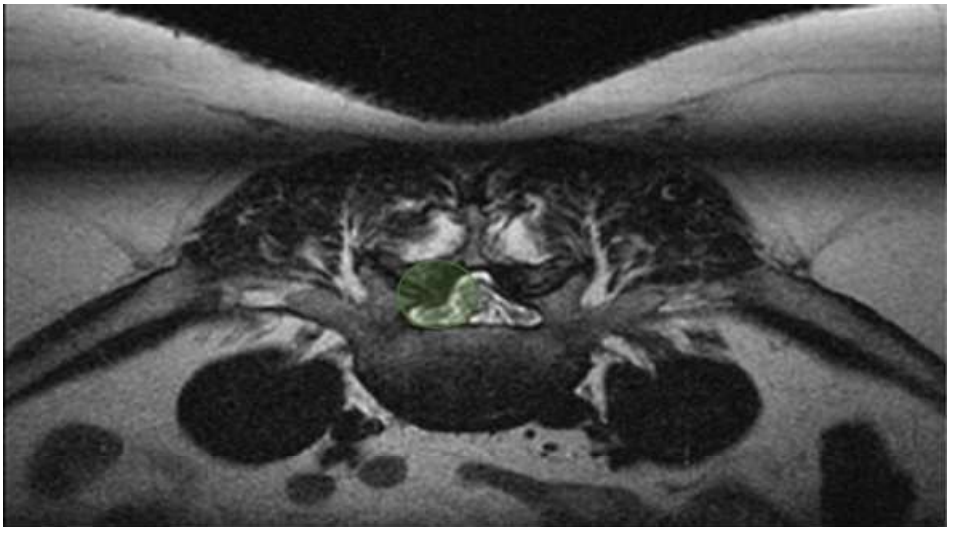
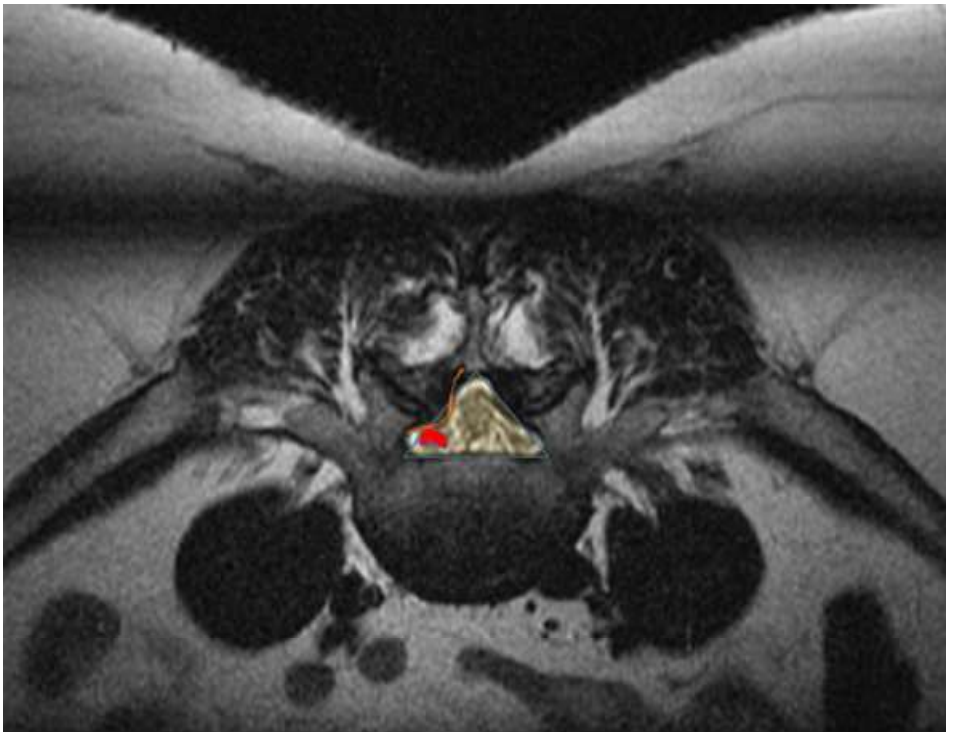


Image 47/3, 4. From middle zone lower border as we go down we see change in facet capsule and subarticular area left of image. Facets are 45 degrees but right facet has capsular+ ligamentum changes. Red dot in image is nerve root yet medial to facet edge. This is yet part 1 of LR as foramen is open.





Images 47/5, 6. We see further changes in right facet subarticular region as marked in green circle. The nerve is exactly under facet edge. There is a loss of symmetry of the dural sac and nerve seems to be settling into lateral recess now. We are in part 2 of LR as we have pedicle as lateral wall in recess. Red is nerve under SAP lateral to edge of the facet.



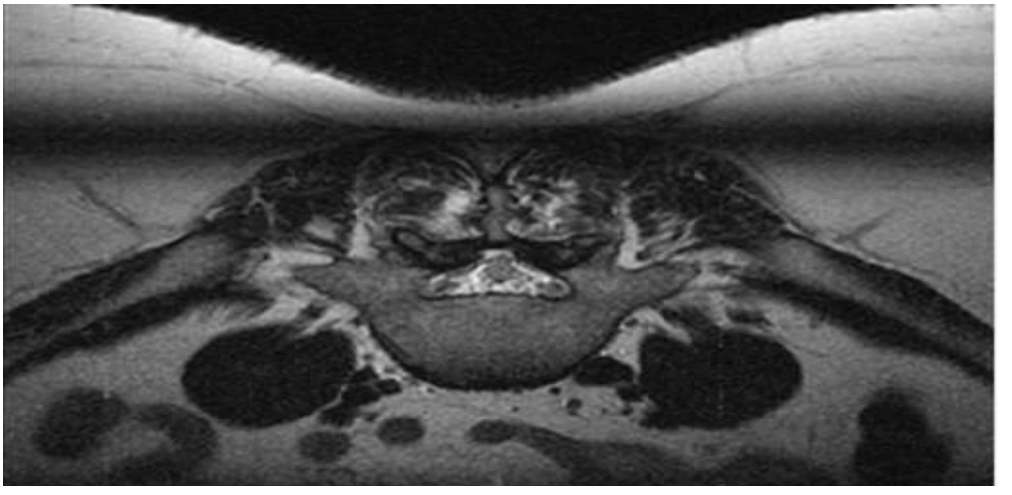
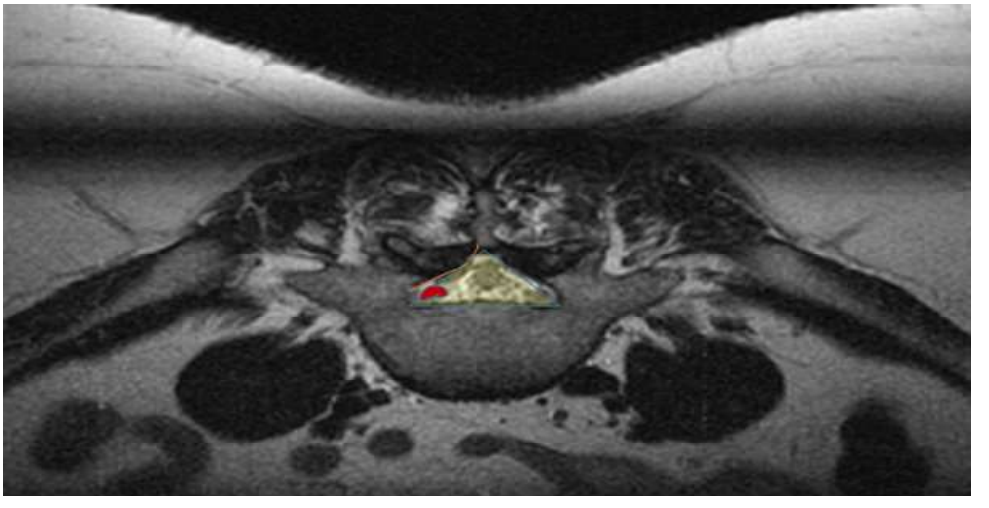


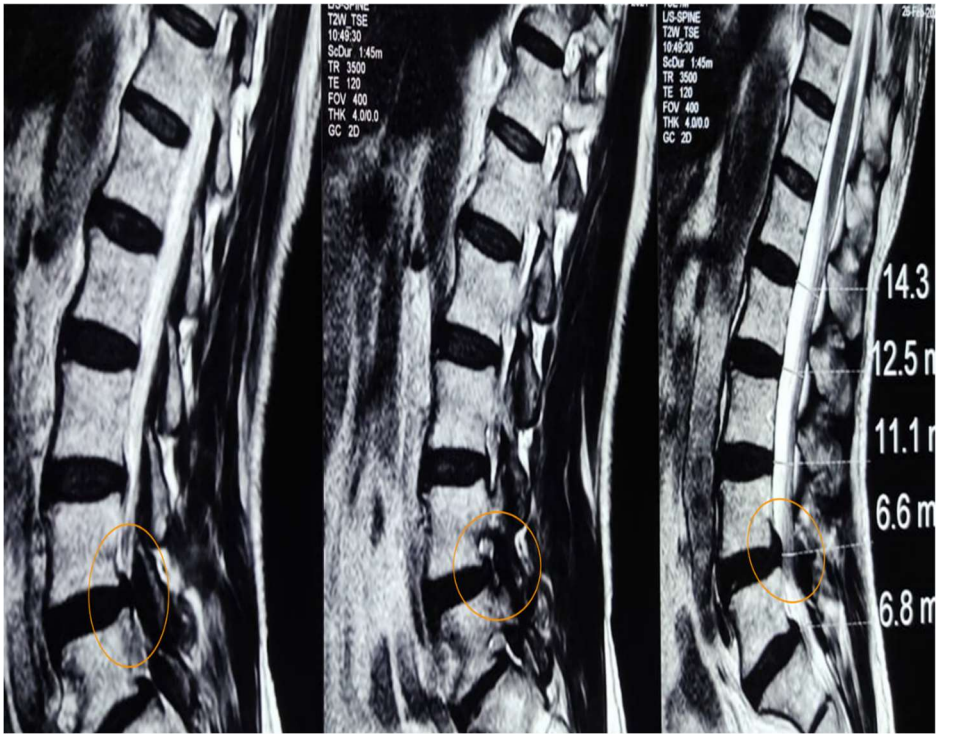
Image 47/7, 8. Nerve is now lateral to facet edge but we still facet asymmetry. Crowding of roots is still evident. There is a subtle asymmetry of dural sac that is triangular now. Arrangement of the facet is still such that IAP is dorsal to SAP and medial.

It may be possible to treat this by posterior access and medial facetectomy as cause is related to posterior wall. Since TFE we enter lateral canal and LR we can do a better job. With flexible curette it is possible to scrape off the soft tissue over facet edge under local anesthesia.

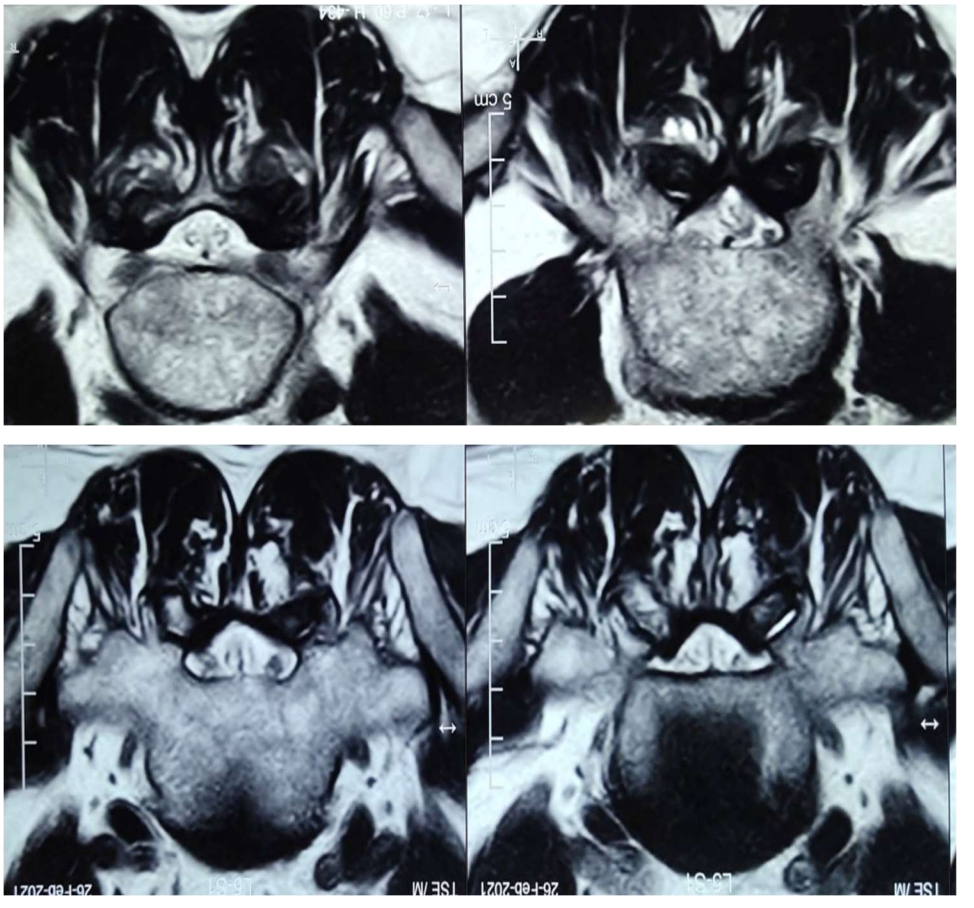


Illustrative Case 4 Images: patient with claudication due to a synovial cyst.

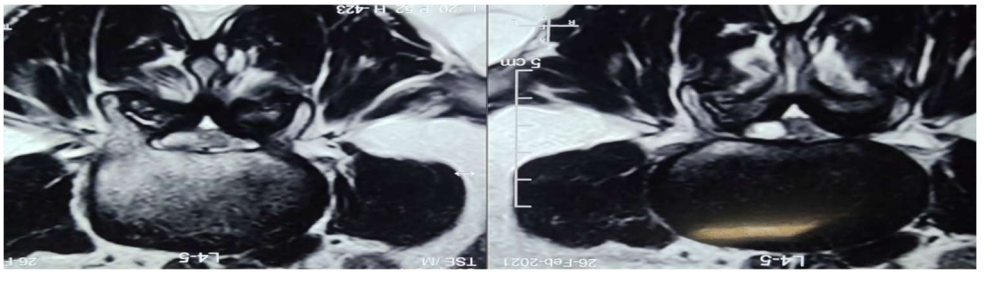
Image 48/1, 2: Patient has a mild listhesis at L45 and further images need to be studied.



Stenotic canal noted at L45mid lower zone involvement seen.

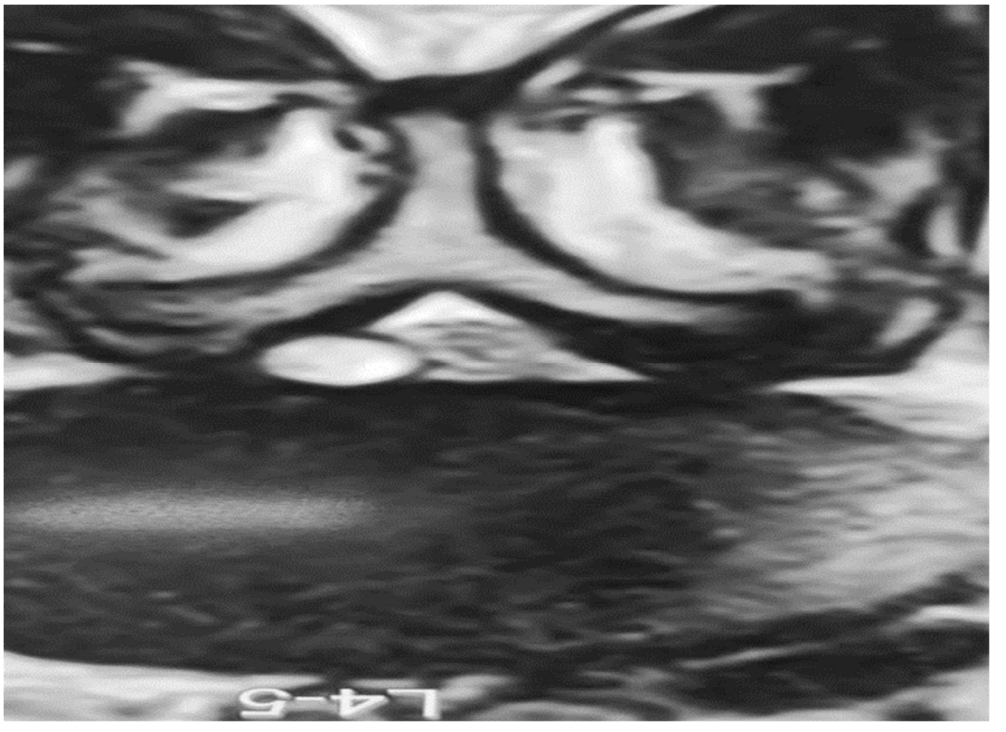


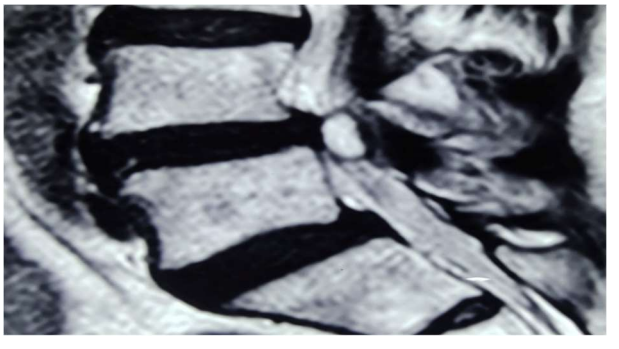
Images 48/3, 4, 5, 6, 7, 8: Axial cuts of upper zone and middle zone seen. No specific cause of symptoms seen in first 4 images.



Images 7, 8 show changes of cyst arising from facet joint on right side. Its location is in lower zone LR up to lower border or even below lower zone boundaries. Cyst is pushing dural sac towards left. This is arising from L45 facet. Cyst occupies complete LR.

Image 48/9, 10 shows cyst inside pedicle wall, here in part 1and 2.





Cyst is seen in Sag image extending to lower zone.

Parasagittal sections show the cyst along medial wall of pedicle.

Mid pedicle landing on lower endplate area. Entry shallow in canal. Needle can go dorsal to sac, along facet face. Under vision excision of the cyst wall can be done. If we do an arthrogram, cyst may be lighted up with dye. Awake and aware patient helps by feedback.

4 Appendix I VAJRA: INTRADISCAL titanium expandable spacer:

In case of collapsed disc we have an intradiscal spacer that I introduced in India in January 2004 during MISS 2004 with Dr Gepstein. This is now relaunched 2021. Here are few of the pics during cadaver demo and surgery.

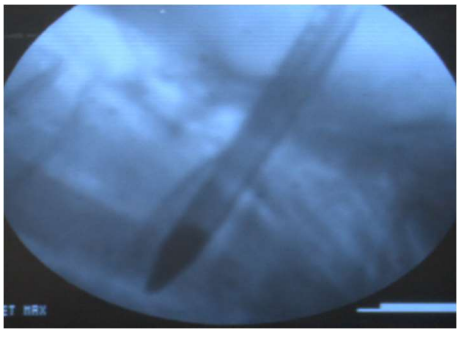
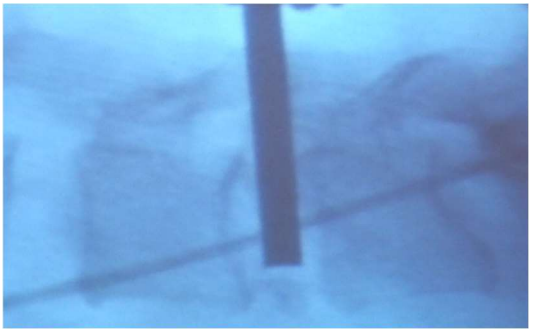
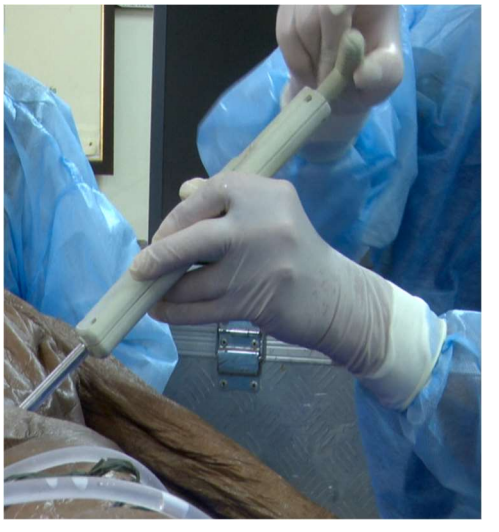



Image 1 Intra operative depth measurement for vajra

Image 2 Full depth of disc covered [Cadaver demo].

Image 3 4 below CADAVER DEMO

Implant is pre-loaded on an inserter, seen here. It is being introduced in disc space through foramen. Using rotations of the t handle we expand the spacer. LIKE A CAR JACK. If posterior tension band is intact then this is enough to stabilise the functional segment.



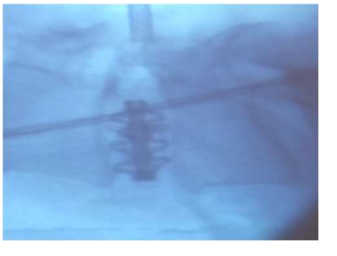


Image 5, 6, and 7 IN LIVE SURGERY expanded spacer in disc space before detaching handle.

Vajra insertion follows disc surgery, where disc has collapsed or we have removed a large fragment where collapse is expected in short term. Preoperative counselling about need for intra discal expandable implant is done. This surgery can be performed under local anaesthesia. We try to go as anterior as possible in disc after putting bone grafts anteriorly if necessary in live surgery. Implant loaded with inserter, implant intradiscal fully deployed. The titanium implant comes in 4 sizes and has lordotic shape. It can be deployed under local anaesthesia and surgery can be done under c arm imaging control. Unilateral use in case of deformity is possible. It can also be done biportal access bilaterally. Identification of disc collapse is by seeing relation of IEL inferior disc endplate line and tip of SAP. They are normally in one line. SAP riding up is a sign of disc collapse.

Appendix II THE TEKU system [patent pending]: Cadaver Demo

Trajectory is now standardized and validated for disc surgery. We have realized that since we need to be safe we mandated floor landing in safe triangle and need to anchor in annulus. The target in stenosis being roof, bony or soft tissue we have now developed our patented teku technology where we use the natural or artificial fulcrum cum anchor outside foramen. This is separation in space of anchor and working tip.

This helps us in properly addressing the roof without expensive equipment like bendable drills or laser. Simple hand-held battery-operated burr is enough. Our lateral entry through foramen is uniquely positioned to give us an access to anterior, lateral or posterior walls, and to all zones upper, middle and lower in one entry with free manoeuvrability built in the teku concept.

I have realized that accessing roof of the foramen in upper zone is easy as size of foramen is large. In middle and lower zone it is difficult in severe stenosis. The new teku system is a fulcrum for our rigid instruments onwards to foramen. Transverse process plane we traverse during our landing in foramen. Transverse processes are strong cortical bone. For L45 we use both L4 and L5 Transverse process base and our teku across both transverse processes.

Transverse process of L5 forms upper margin of bony triangle outside foramen of L5S1. The transverse process of L5 can be a strong fulcrum and anchor for the cannula at L5S1 accessing roof and inner wall of the lateral recess. If spine is osteoporotic we use a retractable insert across transverse processes of L4 and L5 together as base anchor and fulcrum to work against bony roof of the stenotic canal even from a distance to foramen. [Patent pending].

Below are images showing use of extra foraminal teku on L4L5 transverse process. Needle being put medial to teku then entering foramen above the teku very close to foramen but under the facet. Images show use of transparent cannula where surrounding tissue is seen clearly and tube being radiolucent we can see C arm images of surgical field more clearly.

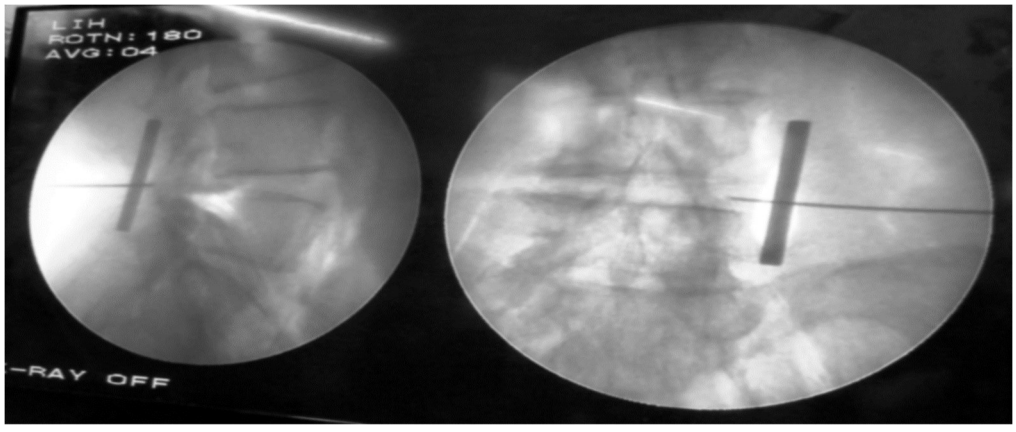


Image 1 shows TEKU on TP needle close and under facet.

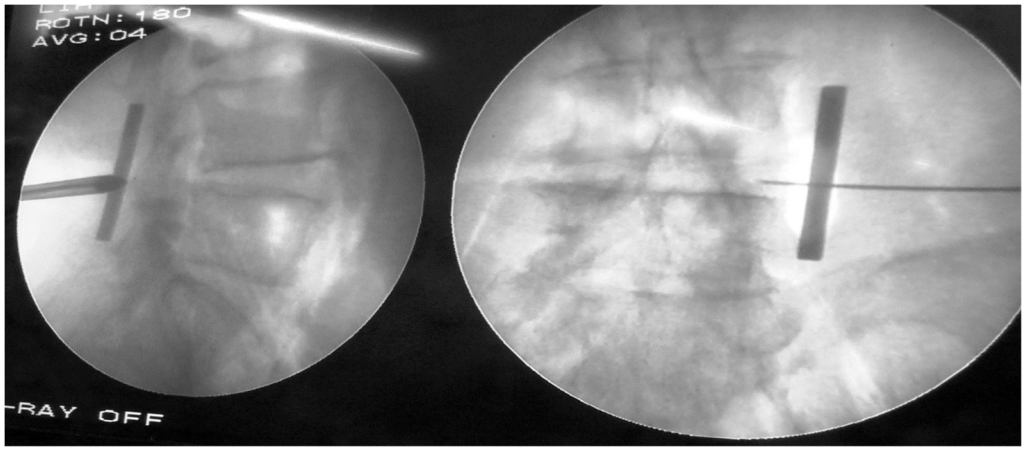


Image 2 Needle is replaced by guidewire and then dilator.

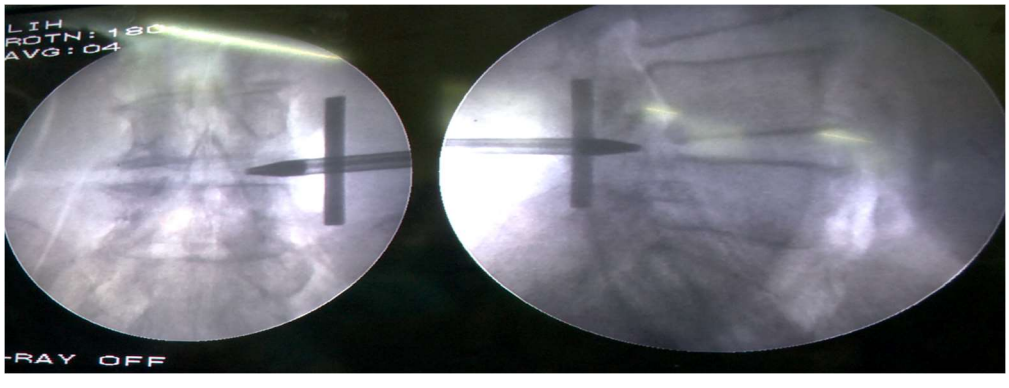


Image 3 Dilator is grazing under surface of facet and we are in foramen and not canal yet. We are outside disc in a much dorsal plane.

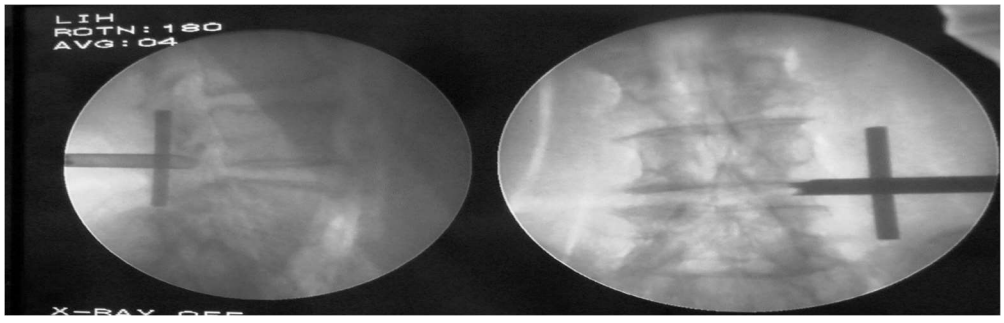


Image 4 the dilator is replaced with a cannula, or transparent cannula.

We can then work on facet and roof with a better grip and force and appose face of the bone easily.

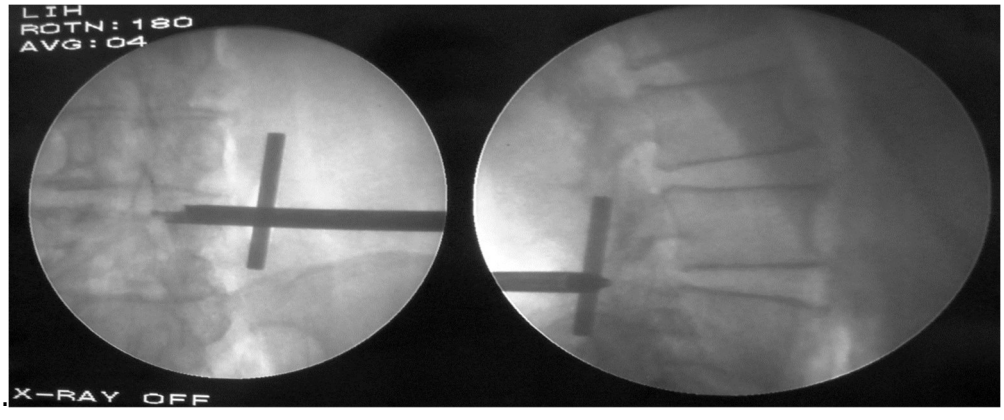
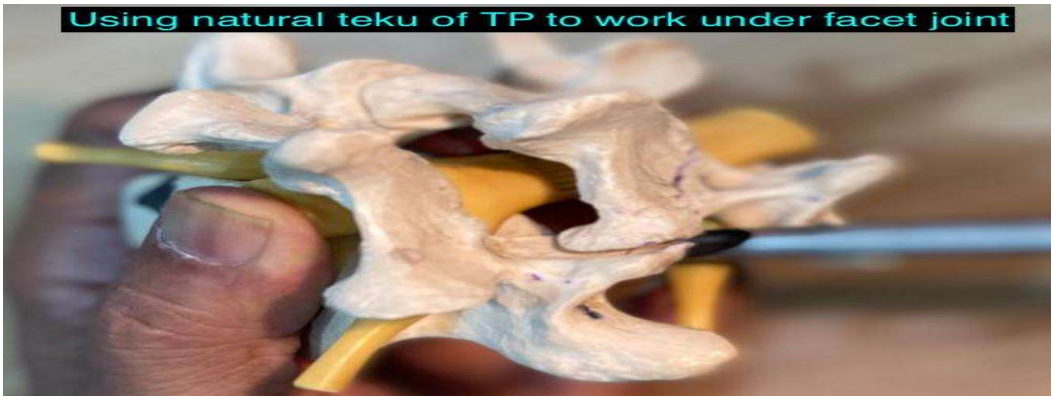


Image 5 working on lateral recess roof and can go dorsal to nerve under vision without much difficulty.

If our main target is posterior wall only; using teku technology is very helpful. In case of L5S1 we use natural teku of transverse process of L5.



Appendix 3: Rethink needed in lumbar stenosis

The author is proposing a new way of looking at clinical analysis, imaging, anatomy, pathology, and a surgeon's approach to cover the likely causative pathology during transforaminal endoscopy in an awake and aware patient for symptomatic developmental stenosis. In patient with discogenic back pain and sciatica, the treatment planning and execution has changed as we have access to the pain generator during surgery in awake and aware patient. In case of

stenosis since we are treating patients who are stationary at surgery but with symptoms only on movements of walking or prolonged standing, they being awake may not make much difference to symptom analysis or real-time change in symptoms during intervention but since most are aged patients it does make a difference as most associated medical comorbidities can be tackled better during intervention under local anaesthesia in our stitchless surgery. We need to apply our mind to rethink concepts on claudication in developmental lumbar stenosis and utility of what we do and why we do it?

Editorial: Gore S. Stable, developmental; LUMBAR canal stenosis: Rethink needed. J Orthop Allied Sci 2018; 6: S3-7.

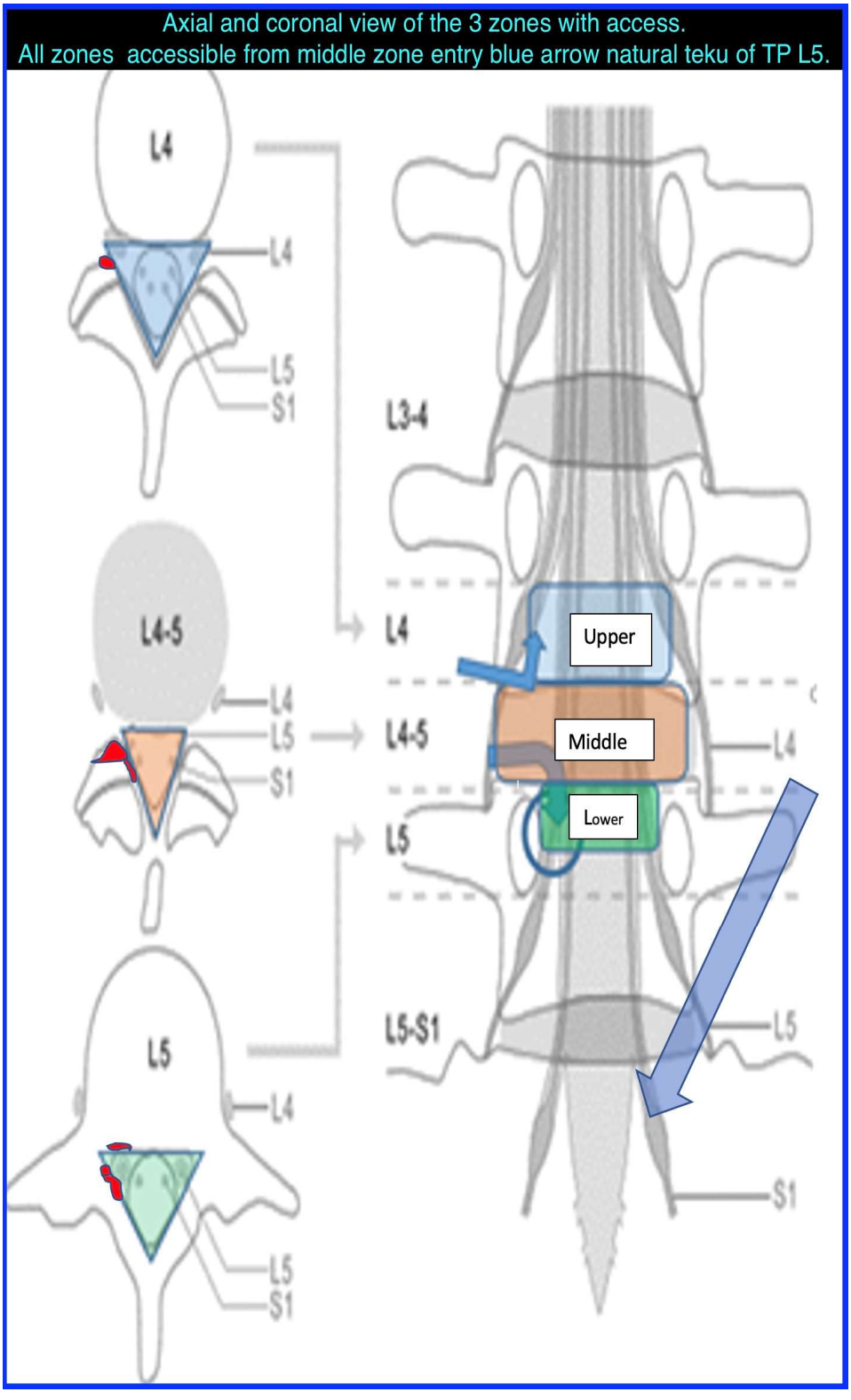
Appendix 4: Endoscopic Foraminal Decompression for Failed Back Surgery Syndrome under local Anaesthesia

Background The most common causes of failed back surgery are residual or recurrent herniation, foraminal fibrosis and foraminal stenosis that is ignored, untreated, or undertreated. Residual back ache may also be from facetal causes or denervation and scarring of the paraspinal muscles. The original surgeon may advise his patient that nothing more can be done on the basis of his opinion that the nerve was visually decompressed by the original surgery, supported by improved post-op imaging and follow-up studies such as EMG and conduction velocity studies. Post-op imaging or electrophysiological assessment may be inadequate to explain all the reasons for residual or recurrent symptoms. Treatment of Failed back surgery by repeat traditional open revision surgery usually incorporates more extensive decompression causing increased instability and back pain, therefore necessitating fusion. The authors, having limited their practice to endoscopic MIS surgery over the last 15-20 years, report on their experience gained during that period to relieve pain by endoscopically visualizing and treating unrecognized causative patho-anatomy in FBSS.

The transforaminal approach to the foramen can offer treatment of patho-anatomy in FBSS not visible by traditional surgical techniques. Treatment options by decompressing the foramen and addressing the endoscopic path-anatomy in the "hidden zone" may offer an effective and less invasive alternative solutions for treating spinal pain. An endoscopic spine surgeon experienced with transforaminal access spine surgery, operating only under local anaesthetic, additionally facilitates recognizing and evaluating nerves in the foramen serving as the mediator of pain from the facets in the axial spine. Visualised ablation of these nerves is effective in decreasing axial back pain component of FBSS during "endoscopic foraminoplasty and rhizotomy."

Author strongly recommends this paper for better insight into transforaminal endoscopy and evolving thinking on stenosis.

Endoscopic Foraminal Decompression for Failed Back Surgery Syndrome under local Anaesthesia Anthony Yeung, Satishchandra Gore International Journal of Spine Surgery Jan 2014, 8 22; **DOI:** 10.14444/1022



Master PLAN: Concept of 3z3w3C GORE SYSTEM in lumbar stenosis.

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