Mass General Brigham
Cancer Institute

AAMD 51st Annual Meeting

Contouring Complex Structures: A Moving Target

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Contouring Complex Structures
Barriers and Strategies to Overcome Them

Pelvic anatomy can be particularly difficult to discern on standard axial CT

- Limitations of CT-simulation imaging isodense structures without fixed positions
- Movement due to peristalsis, bowel and bladder filling, gas, gravity, physical motion

Strategies that can aid contouring

- Oral contrast
- IV contrast
- Diagnostic imaging fusion
- Automated contouring tools
- Sagittal and coronal views
- Bladder full and empty scans
- Other contrast or BBs (urethrogram, anal BB, rectal tubes, vaginal contrast)
- Atlases
- *Discussion*

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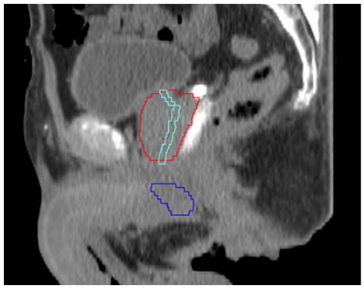
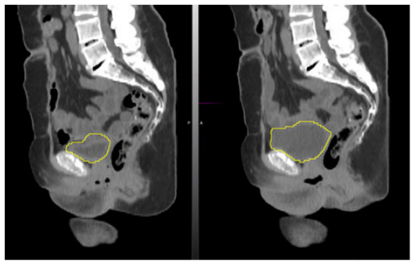
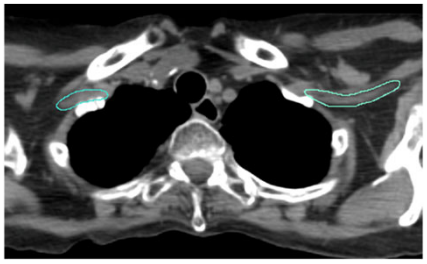
Contouring Complex Structures: A Moving Target

Overview







Complex Pelvic Contours
Pelvic nodal echelons, the prostatic urethra, and the penile bulb can be particularly difficult to discern

Mobile Pelvic OARs
Bowel and bladder are notoriously difficult to localize with certainty

Nervous Plexi
Nervous structures often track a circuitous route and the structures themselves are not always visible on CT imaging

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Contouring Complex Structures
Complex Pelvic Contours

Common Structures of Difficulty

- Pelvic nodal echelons
- Prostatic urethra
- Penile bulb

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Contouring Complex Structures
Complex Pelvic Contours: Pelvic Nodal Stations

Pelvic* Nodal Stations

- Common iliac
- External iliac
- Internal iliac
- Obturator
- Mesorectal
- Presacral
- Inguinofemoral
- Para-aortic

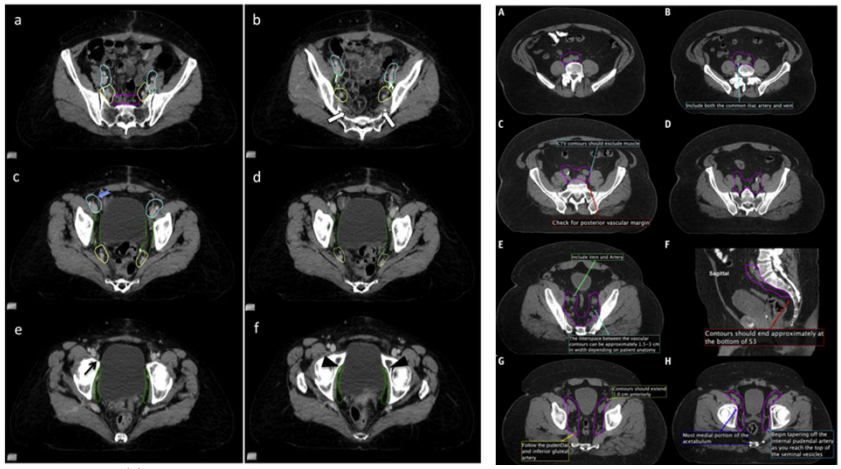
Key Principles in Pelvic Nodal Stations

- Vascular-based, atlases often recommend 7 mm margin on the arteries and veins
- Exclude bone and muscle and fixed OARs
- Include small overlap with mobile OARs (and in particular adjacent mobile bowel)
- Actual targets will vary based on disease site, staging, and involvement

Contouring Complex Structures
Complex Pelvic Contours: Pelvic Nodal Stations

Atlases/Guidelines

- Gynecologic[1]
- Prostate[2]
- Anal[3]
- Rectal[4]
- Anorectal[5]
- NCCN Guidelines

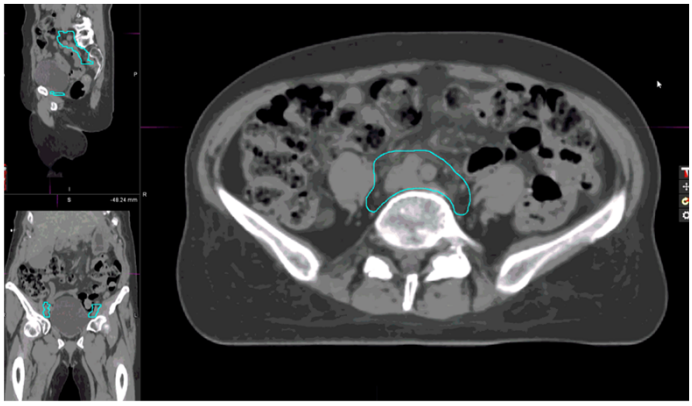


1 Small et al. Int J Radiat Oncol Biol Phys. 2021 Feb 1;109(2):413-424. doi: 10.1016/j.ijrobp.2020.08.061. Epub 2020 Sep 6. PMID: 32905846; PMCID: PMC7856050.
2 Hall et al. Int J Radiat Oncol Biol Phys. 2021 Jan 1;109(1):174-185. doi: 10.1016/j.ijrobp.2020.08.034. Epub 2020 Aug 27. PMID: 32861817; PMCID: PMC7736505.
3 Feng et al. Pract Radiat Oncol. 2025 Jul-Aug;15(4):367-386. doi: 10.1016/j.prro.2025.02.001. Epub 2025 Feb 27. PMID: 40023252.
4 Wo et al. Pract Radiat Oncol. 2021 Jan-Feb;11(1):13-25. doi: 10.1016/j.prro.2020.08.004. Epub 2020 Oct 21. PMID: 33097436.
5 Myerson et al. Int J Radiat Oncol Biol Phys. 2009 Jul 1;74(3):824-30. doi: 10.1016/j.ijrobp.2008.08.070. Epub 2008 Dec 29. PMID: 19117696; PMCID: PMC2709288.

Contouring Complex Structures
Complex Pelvic Contours: Pelvic Nodal Stations

Key Decisions

- Nodal echelons to cover
- Bowel and adjacent OAR exclusions
- Extent of presacral space to cover
- Transition from external iliac to inguinofemoral



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Contouring Complex Structures
Complex Pelvic Contours: Prostatic Urethra

Key Contouring Points

- The portion of the urethra traversing the prostate
- Responsible for meaningful acute and late toxicity
- Highly variable in contouring[1]
- MRI is preferred (T2 sequence)

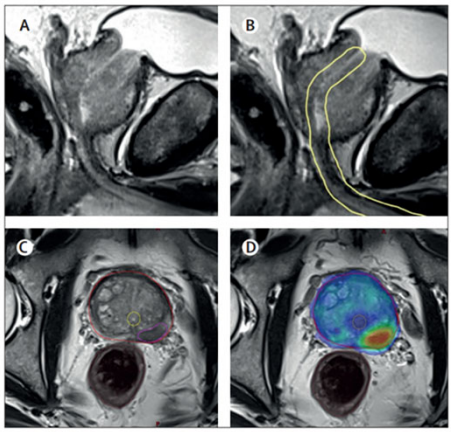

Figure 3: **Urethral-sparing radiotherapy on a series of T2-weighted MRI slices**
Sagittal section showing the course of the urethra (A), outlined in yellow (B). Axial section through the prostate demonstrating a dominant intraprostatic lesion in the 5 o'clock position (C), and radiotherapy dose colour wash applied, showing maximal dose to the dominant intraprostatic lesion in red, and minimal dose to the central urethra in blue (D). Red=prostate. Purple=dominant intraprostatic lesion. Yellow=urethra.

1 Tonneau et al. Radiother Oncol. 2026 Jan;214:111240. doi: 10.1016/j.radonc.2025.111240. Epub 2025 Oct 28. PMID: 41167280.
Image from: Martin et al. Lancet Oncol. 2022 Dec;23(12):e534-e543. doi: 10.1016/S1470-2045(22)00544-7. PMID: 36455582.

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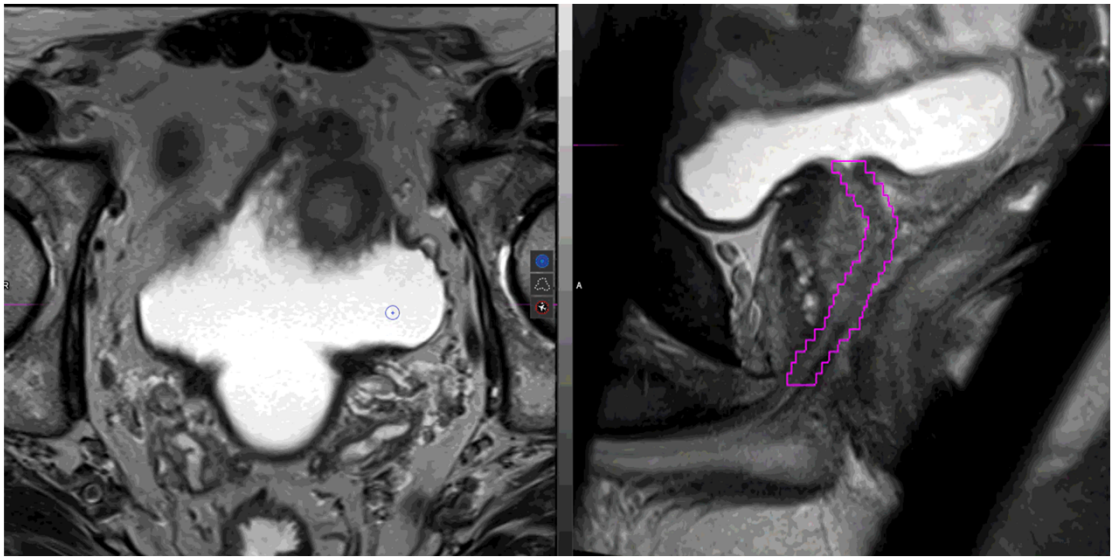
Contouring Complex Structures
Complex Pelvic Contours: Prostatic Urethra



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Contouring Complex Structures
Complex Pelvic Contours: Penile Bulb

Key Contouring Points

- Bulbous spongiosum of the penis immediately inferior to the genitourinary diaphragm
- Surrogate for adjacent critical erectile structures
- Should be oval
- Variable distance from prostate due to GU diaphragm
- MRI is preferred for delineation

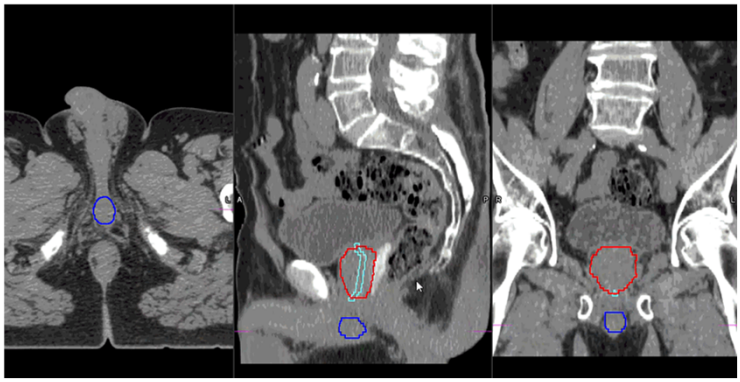

Image from: Lee et al. Lancet Oncol. 2016 May;17(5):e198-208. doi: 10.1016/S1470-2045(16)00063-2. Epub 2016 Apr 27. PMID: 27301047.

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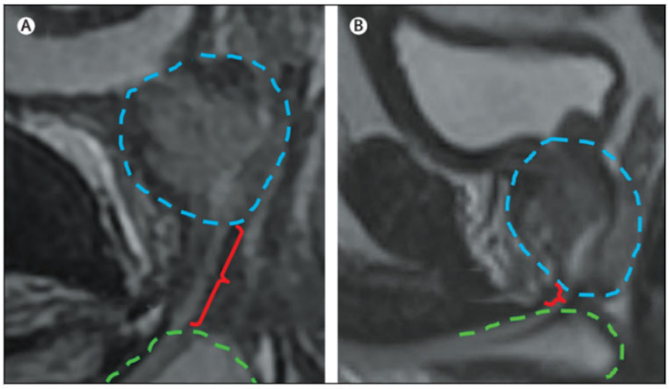

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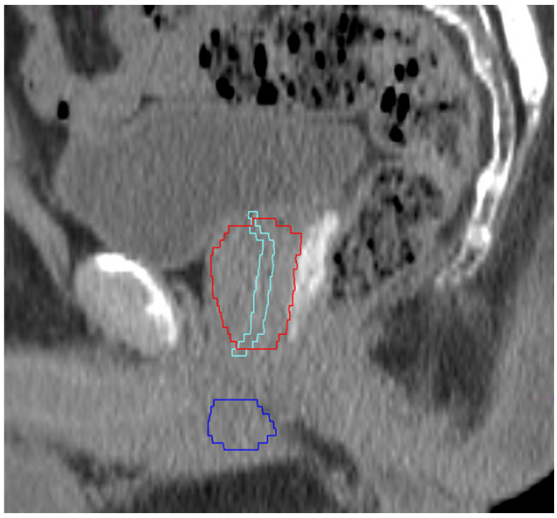
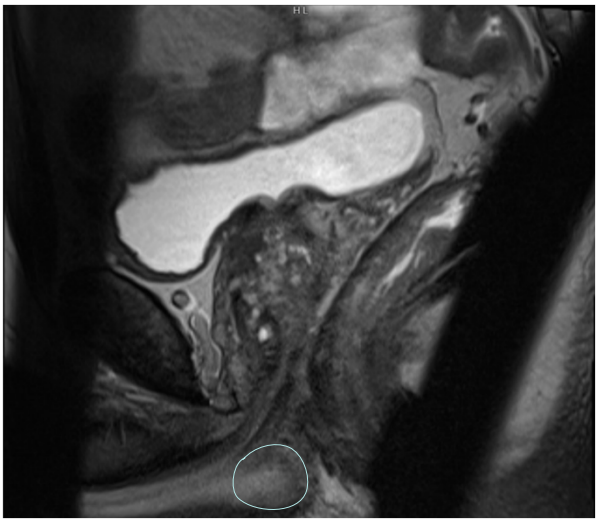
Contouring Complex Structures
Complex Pelvic Contours: Prostatic Urethra and Penile Bulb





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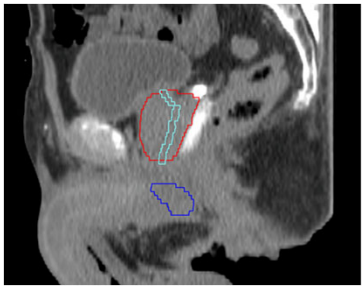
Contouring Complex Structures: A Moving Target

Overview



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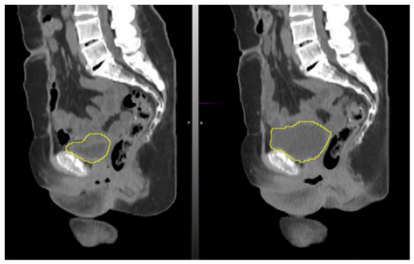

Mobile Pelvic OARs
Bowel and bladder are notoriously difficult to localize with certainty

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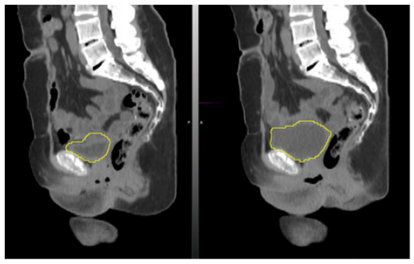
Contouring Complex Structures
Mobile Pelvic OARs

Mobile Pelvic Organs at Risk

- Bladder
- Bowel
  - Rectum
  - Sigmoid
  - Colon
  - Small bowel



Mobile Pelvic OARs
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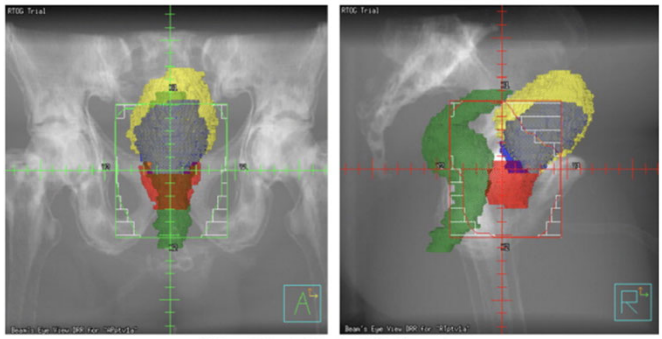
Contouring Complex Structures
Mobile Pelvic OARs: Bladder

Key Considerations

- CT with contrast and MRI can help delineate superiormost and inferiormost extents and distinguish from adjacent organs
- Contoured as a solid structure, though bladder wall[1], or other substructures[2], may represent more accurate risk structures



Yellow = Distended planning CT bladder contour
Blue = Random CT bladder contour during 1st week

FIG. 3

Image of the bladder taken during the initial planning computed tomography and a random day during the first week of patient's radiation course.

1 Harsolia et al. Int J Radiat Oncol Biol Phys. 2007 Nov 15;69(4):1100-9. doi: 10.1016/j.ijrobp.2007.04.076. PMID: 17967304. (Image)
2 Mylona et al. Int J Radiat Oncol Biol Phys. 2019 Jun 1;104(2):343-354. doi: 10.1016/j.ijrobp.2019.01.088. Epub 2019 Feb 2. PMID: 30716523.

Contouring Complex Structures
Mobile Pelvic OARs: Bladder

Strategies to address bladder motion

- CT-sim with empty and full bladder
- Daily IGRT
- Bladder filling instructions
- Adaptive treatment/plan-of-the-day
- Disease-site-specific (and prescription-specific) DVH constraints[1]
- No routine use of PRV approach

Table 22 Postoperative prostate: conventionally fractionated regimens (1.8-2 Gy per fraction to 64-72 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[72]	V65Gy	<50%	≤57.5%	>57.5%*	Bladder – CTVp
	V40Gy	≤70%	≤77%	>77%	
Bowel, Large	D0.03cc	≤62.5 Gy*		>62.5 Gy*	

Table 23 Prostate: ultrahypofractionated 5 fraction regimens (7.25-8 Gy per fraction to 36.25-40 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[64,68]	V37Gy	<5 cc	<20 cc	≥20 cc	
	V18.1Gy	<40%		≥40%	
Bowel, Large[68]	D0.03cc	≤36.25 Gy*		>36.25 Gy*	

Table 24 Rectal: conventionally fractionated regimens (1.8-2.0 Gy per fraction to 50-56 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[80-83]	V45Gy	≤15%	≤30%	>30%*	
	Mean	≤40 Gy	≤44 Gy	>44 Gy	
Bowel, Small	D0.03cc	≤55 Gy*	≤60 Gy*	>60 Gy*	Contoured as

Table 25 Rectal: short-course regimen (5 Gy per fraction to 25 Gy)

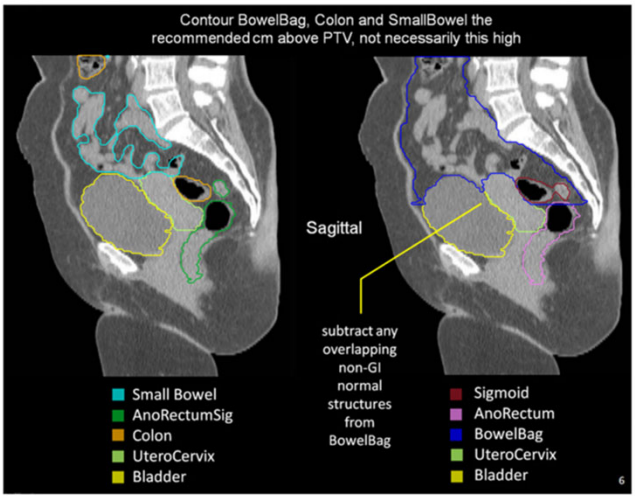
Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[83]	V25Gy	≤20%*	>20%*		
	V15Gy	≤50%	>50%		
	Mean	≤20 Gy*	>20 Gy*		

1 Puckett LL, Apisarnthanarax S, Ballas LK, Chera BS, Chetty IJ, Dawes SL, DeMarco J, Eyler CE, Goodman KA, Jacqmin D, Katsoulakis E, Bang CK, Kujundzic K, Nichols EM, Pursley J, Rosu-Bubulac M, Simone CB 2nd, Xia P, Solanki AA. Dose-Volume Histogram Compendium of Dose Constraints for Treatment Planning: An ASTRO Consensus Paper. Pract Radiat Oncol. 2026 May-Jun;16(3):294-317. doi: 10.1016/j.prro.2025.11.003. Epub 2026 Jan 22. PMID: 41569222.

Contouring Complex Structures
Mobile Pelvic OARs: Bowel

Key Considerations

- PRV (bowel bag) vs. OAR (bowel loops)
- GU and Gyn cases often incorporate a bowel bag approach while GI (esp. upper abdominal cases) favor bowel loops[1,2]



1 Gay et al. Int J Radiat Oncol Biol Phys. 2012 Jul 1;83(3):e353-62. doi: 10.1016/j.ijrobp.2012.01.023. Epub 2012 Apr 6. Erratum in: Int J Radiat Oncol Biol Phys. 2012 Sep 1;84(1):7. PMID: 22483697; PMCID: PMC3904368. (CT Image)
2 Jabbour et al. Pract Radiat Oncol. 2014 Mar-Apr;4(2):82-89. doi: 10.1016/j.prro.2013.06.004. Epub 2013 Aug 7. PMID: 24890348; PMCID: PMC4285338.

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Contouring Complex Structures
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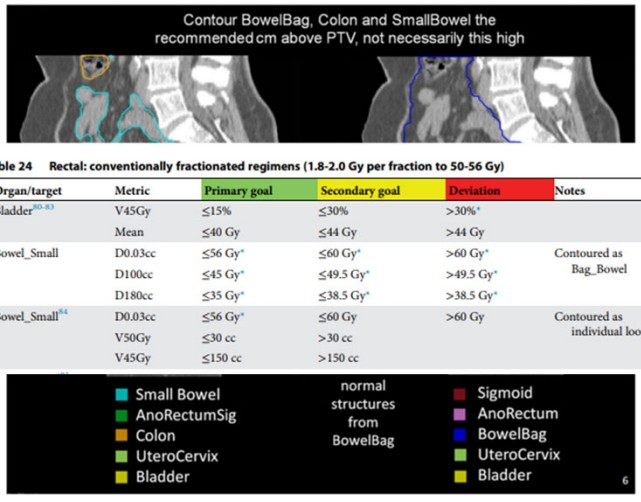
- DVH constraints differ depending on approach[3]



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Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[80-83]	V45Gy	≤15%	≤30%	>30%*	
	Mean	≤40 Gy	≤44 Gy	>44 Gy	
Bowel_Small	D0.03cc	≤56 Gy*	≤60 Gy*	>60 Gy*	Contoured as Bag_Bowel
	D100cc	≤45 Gy*	≤49.5 Gy*	>49.5 Gy*	
	D180cc	≤35 Gy*	≤38.5 Gy*	>38.5 Gy*	
Bowel_Small[84]	D0.03cc	≤56 Gy*	≤60 Gy	>60 Gy	Contoured as individual loops
	V50Gy	≤30 cc	>30 cc		
	V45Gy	≤150 cc	>150 cc		

1 Gay et al. Int J Radiat Oncol Biol Phys. 2012 Jul 1;83(3):e353-62. doi: 10.1016/j.ijrobp.2012.01.023. Epub 2012 Apr 6. Erratum in: Int J Radiat Oncol Biol Phys. 2012 Sep 1;84(1):7. PMID: 22483697; PMCID: PMC3904368. (CT Image)
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3 Puckett et al. Pract Radiat Oncol. 2026 May-Jun;16(3):294-317. doi: 10.1016/j.prro.2025.11.003. Epub 2026 Jan 22. PMID: 41569222. (Constraint Table)

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Contouring Complex Structures
Mobile Pelvic OARs: Bowel

Accounting for Bowel Motion

- Physical displacement
  - Prone positioning
  - Full bladder
- Contouring surrogates
  - Bowel bag
- Advanced techniques
  - IMRT/VMAT
  - MR-linac

Contouring Tips

- When using coplanar beams, contouring can stop 1 cm above PTV
- Bowel loops should be contoured tightly as such
- Absolute volume is most relevant and will not be impacted by extent of contouring outside treatment area
- Broad avoidance structures may be helpful in planning

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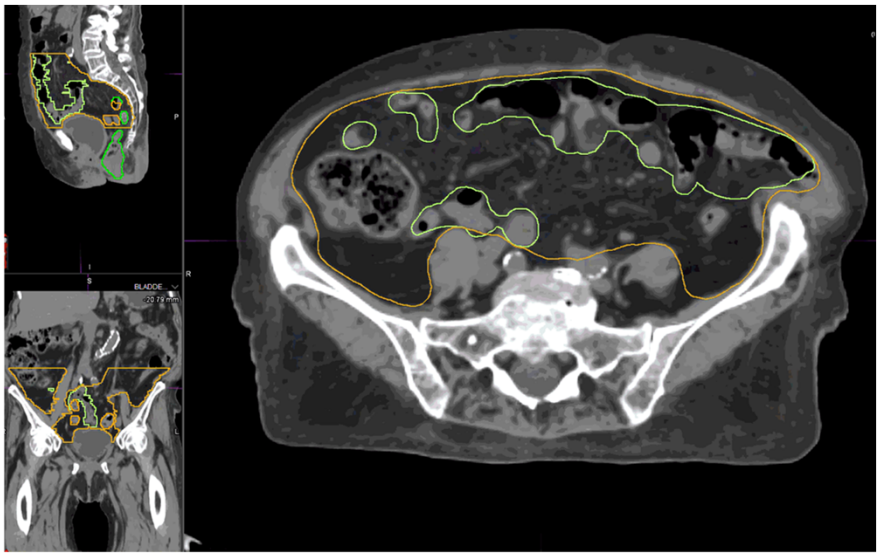
Contouring Complex Structures
Mobile Pelvic OARs: Bowel



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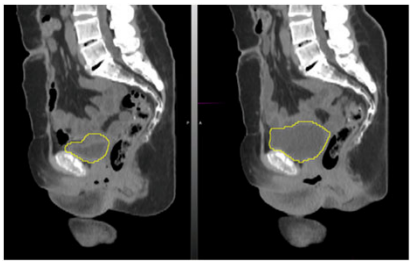
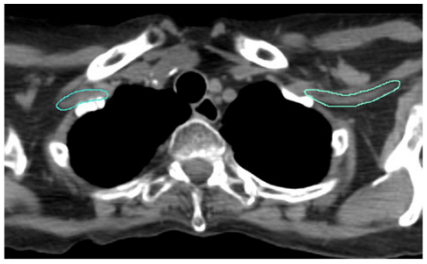
Contouring Complex Structures: A Moving Target

Overview





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Nervous structures often track a circuitous route and the structures themselves are not always visible on CT imaging

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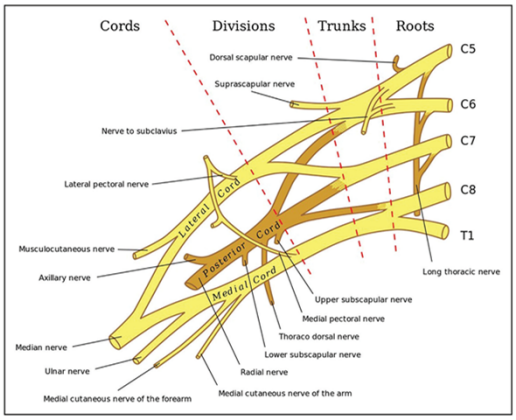
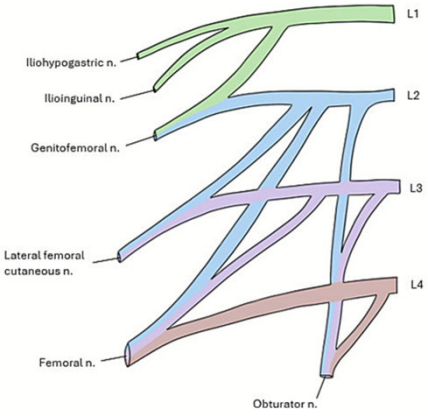
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



1 Fockens et al. Curr Opin Otolaryngol Head Neck Surg. 2023 Apr 1;31(2):105-110. doi: 10.1097/MOO.0000000000000869. Epub 2022 Dec 29. PMID: 36912222.

Lumbosacral Plexus



2 Beutler et al. Clin Imaging. 2026 Jan;129:110675. doi: 10.1016/j.clinimag.2025.110675. Epub 2025 Nov 14. PMID: 41252793.

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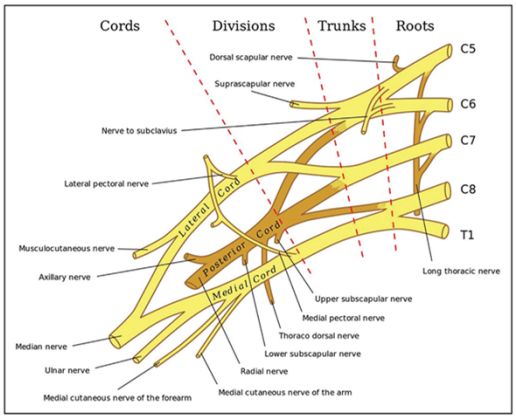
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



1 Fockens et al. Curr Opin Otolaryngol Head Neck Surg. 2023 Apr 1;31(2):105-110. doi: 10.1097/MOO.0000000000000869. Epub 2022 Dec 29. PMID: 36912222.

Key Considerations

- Anatomical variations are common[1]
- Contouring begins at C5–T1, follows between the anterior and middle scalene muscles, and extends inferolaterally past the subclavian vessels
- MRI fusion can improve identification, particularly laterally[2]
- Constraints will vary by clinical context:
  - concurrent, prior, or planned chemotherapy
  - dose and fractionation scheme
  - prior radiation

2 Truong et al. Radiographics. 2010 Jul-Aug;30(4):1095-103. doi: 10.1148/rg.304095105. PMID: 20631370.

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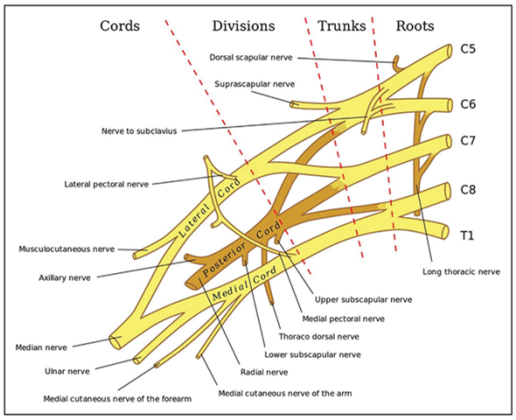
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



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Atlas Guidance

- RTOG atlas[2,3]
  1. Identify and contour C5, T1, and T2.
  2. Identify and contour the subclavian and axillary neurovascular bundle.
  3. Identify and contour anterior and middle scalene muscles from C5 to insertion onto the first rib.
  4. To contour the brachial plexus OAR use a 5-mm diameter paint tool.
  5. Start at the neural foramina from C5 to T1; this should extend from the lateral aspect of the spinal canal to the small space between the anterior and middle scalene muscles.
  6. For CT slices, where no neural foramen is present, contour only the space between the anterior and middle scalene muscles.
  7. Continue to contour the space between the anterior and middle scalene muscles; eventually the middle scalene will end in the region of the subclavian neurovascular bundle.
  8. Contour the brachial plexus as the posterior aspect of the neurovascular bundle inferiorly and laterally to one to two CT slices below the clavicular head.
  9. The first and second ribs serve as the medial limit of the OAR contour.

2 Hall et al. Int J Radiat Oncol Biol Phys. 2008 Dec 1;72(5):1362-7. doi: 10.1016/j.ijrobp.2008.03.004. Epub 2008 Apr 28. PMID: 18448267.
3 Yi et al. Int J Radiat Oncol Biol Phys. 2012 Mar 1;82(3):1060-4. doi: 10.1016/j.ijrobp.2010.10.035. Epub 2011 Apr 30. PMID: 21536393.

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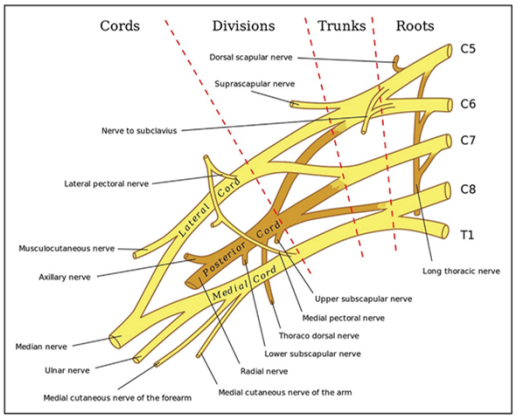
Brachial Plexus



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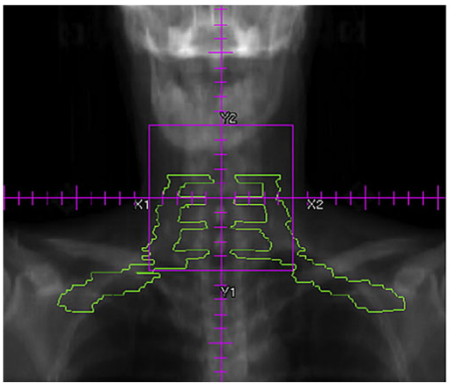
Atlas Guidance

- RTOG atlas[2,3]



2 Hall et al. Int J Radiat Oncol Biol Phys. 2008 Dec 1;72(5):1362-7. doi: 10.1016/j.ijrobp.2008.03.004. Epub 2008 Apr 28. PMID: 18448267.
3 Yi et al. Int J Radiat Oncol Biol Phys. 2012 Mar 1;82(3):1060-4. doi: 10.1016/j.ijrobp.2010.10.035. Epub 2011 Apr 30. PMID: 21536393.

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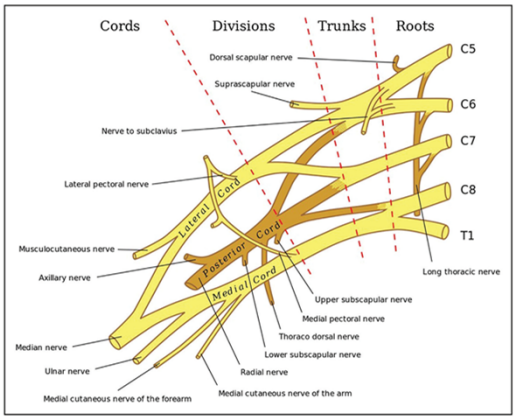
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



1 Fockens et al. Curr Opin Otolaryngol Head Neck Surg. 2023 Apr 1;31(2):105-110. doi: 10.1097/MOO.0000000000000869. Epub 2022 Dec 29. PMID: 36912222.

Atlas Guidance

- RTOG/EORTC/SWOG Thoracic OAR Atlas[2]

1. Locate the neural foramina at the C4-C5 and T1-T2 levels to identify the C5 and T1 roots, respectively
2. Locate the subclavian and axillary neurovascular bundle to identify the lateral aspect of the brachial plexus inferiorly
3. Locate the anterior and middle scalene muscles from the C5 vertebral level to their respective insertions on the first rib
4. Start at the neural foramina at the C4-C5 level and moving caudally; contour the region from the lateral aspect of the spinal canal laterally to the small space between the anterior and middle scalene muscles. At levels at which no neural foramina are present, contour the space or soft tissue between the anterior and middle scalene muscles
5. Continue to contour the space between the anterior and middle scalene muscles; eventually, the middle scalene muscle will terminate in the region of the subclavian neurovascular bundle
6. Contour the brachial plexus structures inferiorly until the region of the subclavian vascular bundle is identified, the second rib should serve as the medial limit

2 Kong et al. Int J Radiat Oncol Biol Phys. 2011 Dec 1;81(5):1442-57. doi: 10.1016/j.ijrobp.2010.07.1977. Epub 2010 Oct 8. PMID: 20934273; PMCID: PMC3933280.

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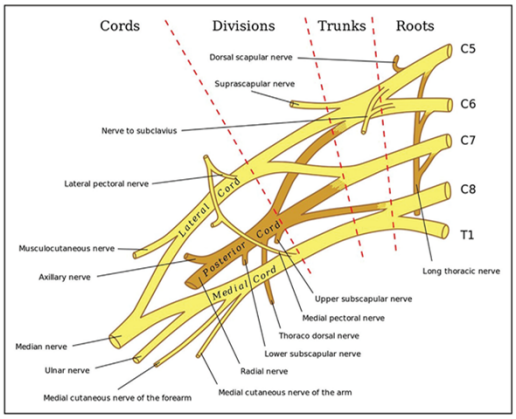
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



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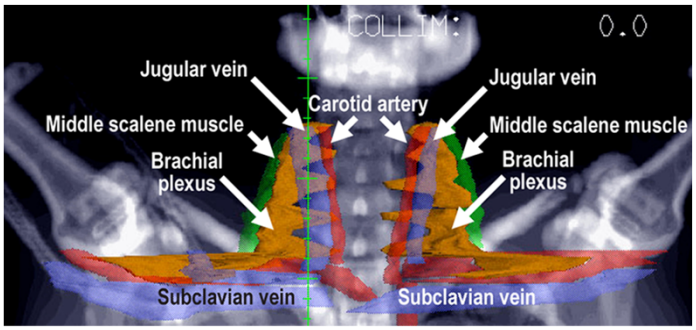
Atlas Guidance

- RTOG/EORTC/SWOG Thoracic OAR Atlas[2]



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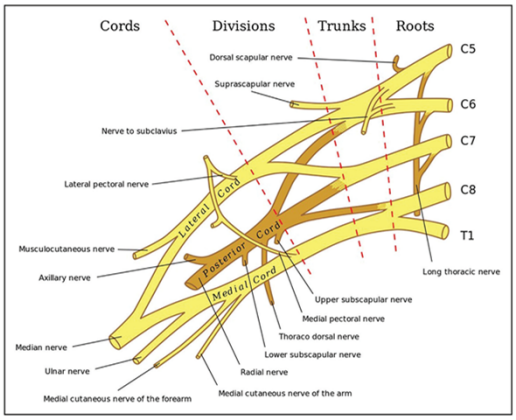
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



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Atlas Guidance

- Truong Atlas[2]

1. Identify the C4–5 and T1–2 neural foramina at sagittal planning CT to determine the upper and lower limits of the brachial plexus (Fig 4).
2. Contour the ventral rami of C5-T1 as they exit through the intervertebral neural foramina as seen at axial CT.
3. Contour the trunks of the brachial plexus between the anterior and middle scalene muscles.
4. Follow the insertion of the scalene muscles into the first rib.
5. Contour the brachial plexus divisions, cords, and terminal nerves by following the subclavian artery into the axilla.

2 Truong. Brachial plexus contouring with CT and MR imaging in radiation therapy planning for head and neck cancer. Radiographics. 2010 Jul-Aug;30(4):1095-103. doi: 10.1148/rg.304095105. PMID: 20631370.

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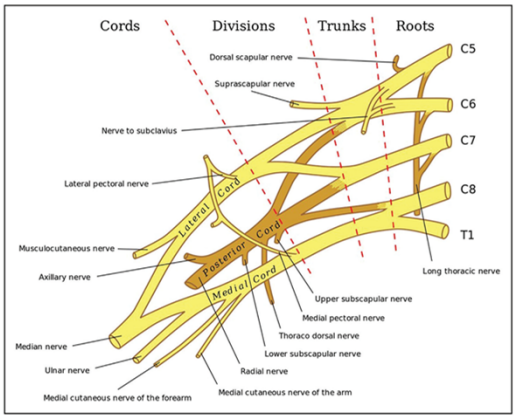
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



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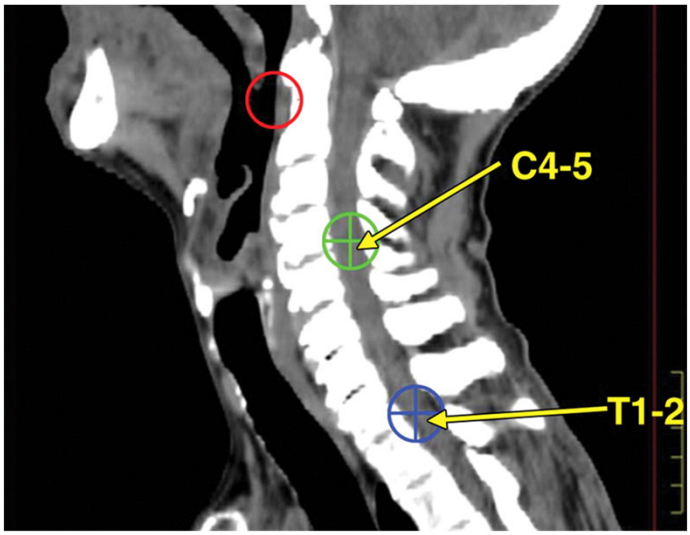

2 Truong. Brachial plexus contouring with CT and MR imaging in radiation therapy planning for head and neck cancer. Radiographics. 2010 Jul-Aug;30(4):1095-103. doi: 10.1148/rg.304095105. PMID: 20631370.

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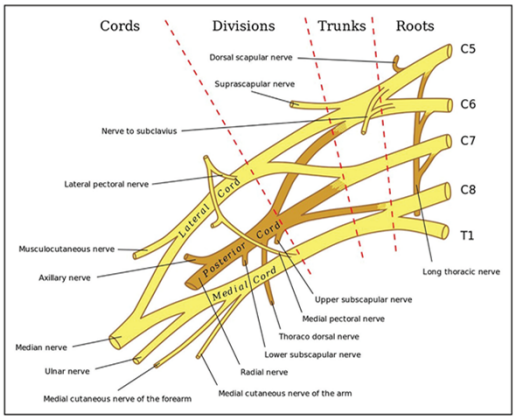
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



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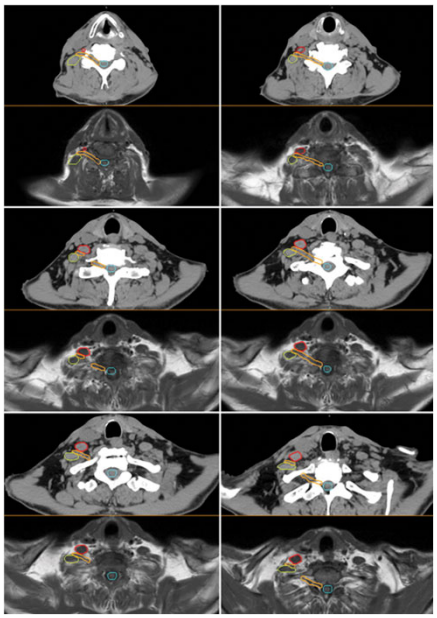
Atlas Guidance

- Truong Atlas[2]



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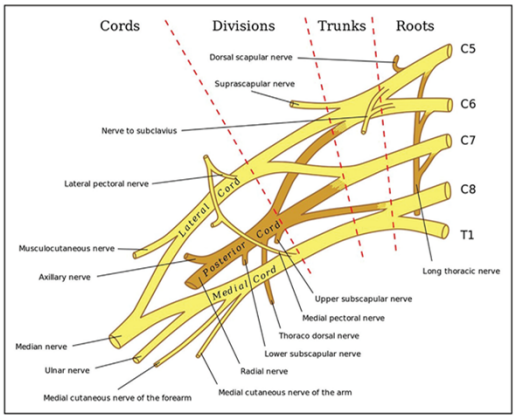
Contouring Complex Structures
Nervous Plexi

Brachial Plexus



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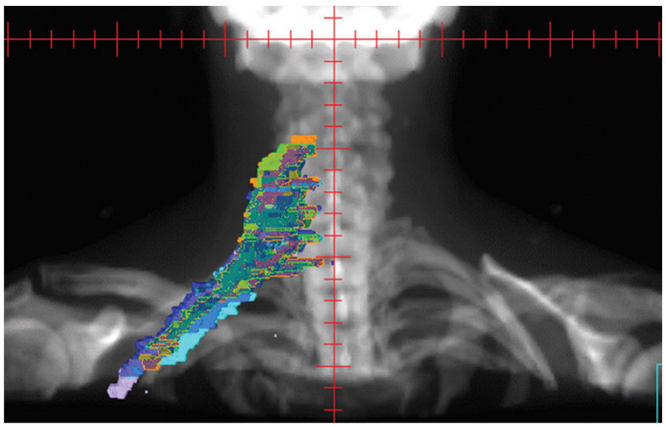
Atlas Guidance



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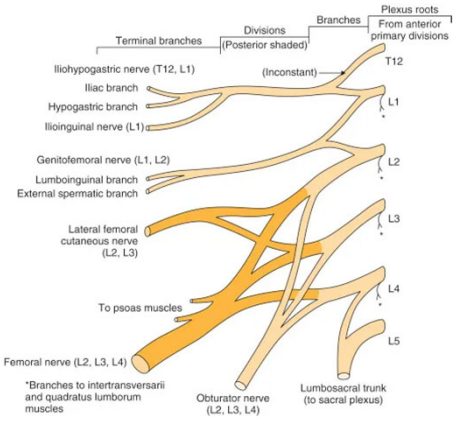
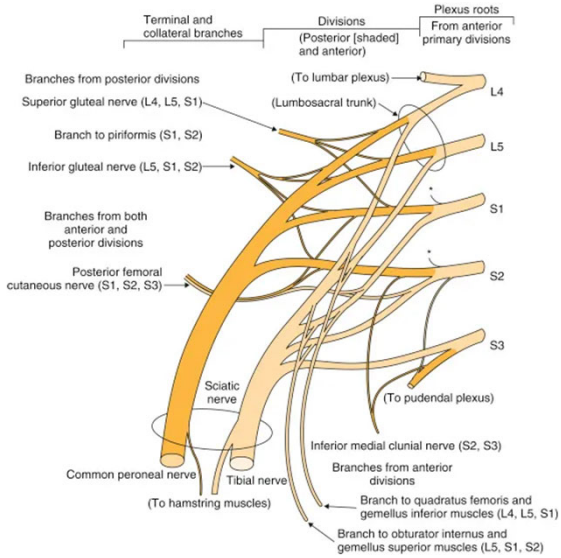
Contouring Complex Structures
Nervous Plexi: The Lumbosacral Plexus

Lumbosacral Plexus





De Groot J, Chusid JG. Correlative Neuroanatomy , 21st ed. Norwalk, CT: Appleton & Lange; 1991.

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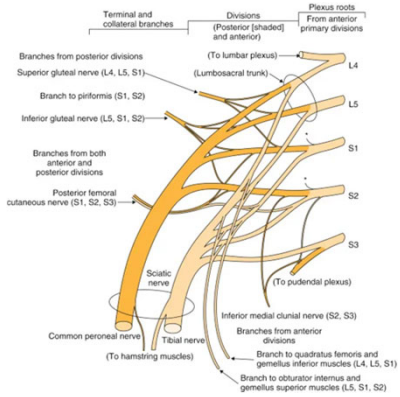
Contouring Complex Structures
Nervous Plexi: The Lumbosacral Plexus

Lumbosacral Plexus



1 De Groot J, Chusid JG. Correlative Neuroanatomy , 21st ed. Norwalk, CT: Appleton & Lange; 1991.

Key Considerations

- Lumbosacral plexus atlases[2-4] have less consensus and support
- Guidance on the treatment of the plexus is not standardized
- Likely most critical with high doses (sarcoma, re-irradiation, SBRT), but RILSP may be under-reported[2]

2 Yi et al. Int J Radiat Oncol Biol Phys. 2012 Oct 1;84(2):376-82. doi: 10.1016/j.ijrobp.2011.11.074. Epub 2012 Feb 17. PMID: 22342301.
3 Cao et al. Front Oncol. 2022 Nov 9;12:818953. doi: 10.3389/fonc.2022.818953. PMID: 36439428; PMCID: PMC9683691.
4 Tunio et al. Onco Targets Ther. 2014 Dec 23;8:21-7. doi: 10.2147/OTT.S71086. PMID: 25565862; PMCID: PMC4278780.

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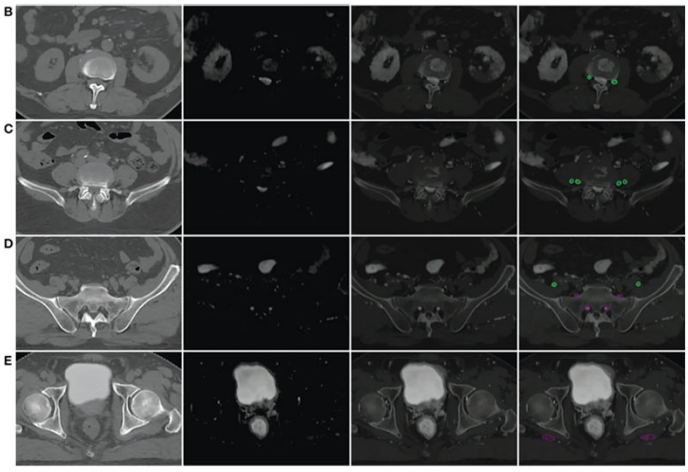
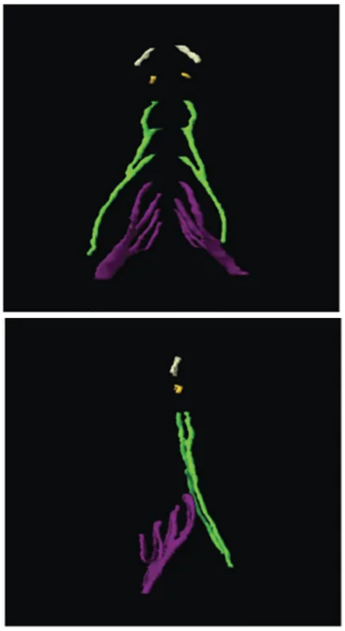
Contouring Complex Structures
Nervous Plexi: The Lumbosacral Plexus

Lumbosacral Plexus





Cao et al. Front Oncol. 2022 Nov 9;12:818953. doi: 10.3389/fonc.2022.818953. PMID: 36439428; PMCID: PMC9683691.

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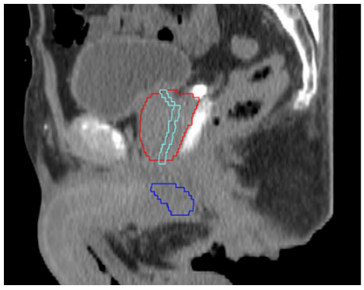
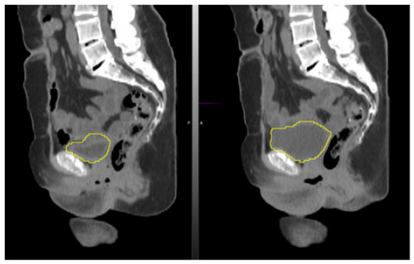
Contouring Complex Structures: A Moving Target

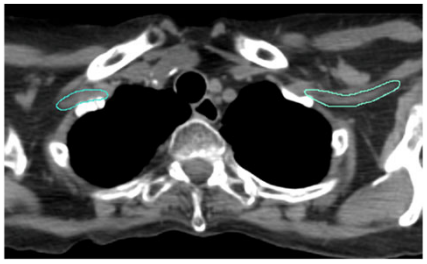
Overview



Complex Pelvic Contours
Pelvic nodal echelons, the prostatic urethra, and the penile bulb can be particularly difficult to discern



Mobile Pelvic OARs
Bowel and bladder are notoriously difficult to localize with certainty



Nervous Plexi
Nervous structures often track a circuitous route and the structures themselves are not always visible on CT imaging

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Acknowledgments

Thank you to AAMD for having me and thank you to my dosimetry colleagues for their patient collaboration and insight.

Thanks to my family for their love, patience, and support.

Questions?

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