Organ: Cochlea
Authors: Bhandare et al
Background: RT to cochlea leads to sensorineural hearing loss (SNHL)
Contouring/Volumes: Contour bony labyrinth on CT, average contour volume 0.13-0.56mL.
Other Factors Affecting Risk: concurrent cisplatin, increasing age, better pre-RT hearing, post-RT otitis media, CSF shunt
Toxicity Endpoint and Rates: SNHL, <25-30%
Recommended Dose-Volume Limits:
<table>
<thead>
<tr>
<th>Cochlea</th>
<th>Conv Fx</th>
<th>Mean Dose &lt; 35-45Gy (lower if concurrent cisplatin)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SRS for VS</td>
<td>PD 12-14Gy</td>
</tr>
<tr>
<td></td>
<td>SRT</td>
<td>21-30Gy in 3-7Gy/fx over 3-10 days</td>
</tr>
</tbody>
</table>

Organ: Parotid, Salivary Glands
Authors: Deasy et al
Background: Xerostomia leads to dental issues, infections, pain. Some function can recover over 2 years.
Parotids: stimulated salivary function
Submandibular/Sublingual: resting salivary function
Contouring/Volumes: Lateral edges can shrink ~1mm/wk!
Other Factors Affecting Risk: Pretreatment salivary function. No proven correlation to age, sex, chemo.
Superficial vs deep lobes?
Submandibular gland sparing can help.
Amifostine.
Toxicity Endpoint and Rates: Xerostomia, <25%
Recommended Dose-Volume Limits:
| 1 parotid | Mean<20Gy |
| both parotids | Mean<25Gy |
| submandibular | Mean<35Gy |

Organ: Larynx
Authors: Rancati et al
Background: goal of larynx preservation chemoRT is to preserve speech and swallowing fcn
Contouring/Volumes: tip of epiglottis to bottom of cricoid, exclude external cartilage
Other Factors Affecting Risk: cancer involvement causing pre-RT dysfunction, concurrent chemo
Toxicity Endpoint and Rates: laryngeal edema, vocal dysfunction. <20%
Recommended Dose-Volume Limits:
| Larynx | V50<27%, Mean<44Gy, Dmax<66Gy |

Organ: Pharynx
Authors: Rancati et al
Background: RTOG 9111 concurrent arm had 23% swallowing dysfunction at 1 yr
Contouring/Volumes: pharyngeal constrictors (for anatomy, see Eisbruch, Red 2004;60:1425)
Other Factors Affecting Risk: cancer involvement causing pre-RT dysfunction, concurrent chemo
Toxicity Endpoint and Rates: dysphagia, <20%
Recommended Dose-Volume Limits:
| Pharyngeal constrictors | Mean<50Gy |
Organ: Lung
Authors: Marks et al
Background: 5-50% incidence of clinically significant symptomatic radiation pneumonitis in pts irradiated for lung cancer. The risk of RP limits the delivered dose and may hamper tumor control.
Contouring/Volumes: Contour as a single paired organ, include atelectatic lung, lots of ambiguity, lungs move
Other Factors Affecting Risk: concurrent docetaxel and gemcitabine (cis/carbo/paclitaxel, etoposide okay), more fractions, non-surgery patients, non-smokers(!)
Toxicity Endpoint and Rates: symptomatic pneumonitis, <20%
Recommended Dose-Volume Limits:
Lung
Whole lung V20 < 30%
Mean dose < 20 Gy

Special cases
Central airways should be limited to < 80 Gy to reduce risk of bronchial stricture
Mesothelioma post pneumonectomy limit V5 to < 60%, V20 < 4-10% and MLD < 8 Gy

Organ: Heart
Authors: Gagliardi et al
Background:
Acute injury: pericarditis, transient but can be chronic
Late injury: CHF, ischemia, CAD, MI, months to yrs post RT, may offset improvements in DSS from adjuvant RT
Highest incidence in: lymphoma, breast, seminoma, lung, and atomic bomb survivors
Contouring/Volumes: heart moves with respiration, difficult to differentiate from vessels, liver, diaphragm
Other Factors Affecting Risk: Baseline cardiac risk factors: age, gender, DM, smoking, HTN, LDL/HDL, FHx MI < 60
Anthracycline based chemo, lymphoma (leading cause of non-cancer mortality in HL patients)
Toxicity Endpoint and Rates: Pericarditis < 15%, long-term cardiac mortality < 1%
Recommended Dose-Volume Limits:
Pericardium V30 < 46%
Mean dose < 26 Gy
Whole heart V25 < 10%

Organ: Esophagus
Authors: Werner-Wasik et al
Background: esophageitis results in admits, invasive diagnostic tests, surgery (PEG), RT breaks (all lower tumor control)
Contouring/Volumes: from cricoids to GE junction, often hard to identify in the middle and caudal levels, circumference varies markedly
Other Factors Affecting Risk: hyperfractionation, concurrent boost, pre-existing dysphagia, concurrent gemcitabine, amifostine?
Toxicity Endpoint and Rates: Grade 3+ acute esophagitis < 20% and Grade 2+ acute esophagitis < 30%
Recommended Dose-Volume Limits:
Esophagus V35 < 50%
V50 < 40%
V70 < 20%
Mean dose < 34 Gy
Organ: Brain
Authors: Lawrence et al
Background: Important late effects of RT to the brain include radiation necrosis and cognitive decline. Radiation necrosis occurs at a median of 1-2 years.
Contouring/Volume: little disagreement regarding segmentation of entire brain
Other Factors Affecting Risk: dose, fraction size, volume, chemotherapy, age, diabetes, surgery, steroids, pain meds
Toxicity Endpoint and Rates:
Radiation Necrosis - dx by symptoms and imaging
Cognitive Dysfunction - varies in definition/testing
Recommended Dose-Volume Limits:
Fractionated RT to partial brain: <3% at 5 years: 60 Gy; 5% at 5 years: 72 Gy (BED 120 Gy); 10% at 5 years: 90 Gy (BED 150 Gy)
Neurocognitive function in children: occurs after >18 Gy WBRT
SRS: keep V12 <5 -10 cm^3

Organ: Optic nerves and Chiasm
Authors: Mayo et al
Background: Radiation induced optic neuropathy causes visual impairment and develops w/in 3 years (median 2.5y)
Contouring/Volume: Recommend using MR fusion for improved definition
Other Factors Affecting Risk: age, diabetes, chemotherapy
Toxicity Endpoint and Rates: Optic neuropathy
Recommended Dose-Volume Limits: whole organ recommendations
Rate <3%: Dmax <55 Gy
Rate 3-7%: Dmax 55-60 Gy
Rate >7%: Dmax >60 Gy
SRS: <10Gy
***** Important note: these recs exclude pts with pituitary tumors where tolerance may be reduced (Dmax <46 Gy).

Organ: Brainstem
Authors: Mayo et al
Background: Brainstem injury from radiation therapy includes necrosis and cranial neuropathies
Contouring/Volume: includes midbrain, pons and medulla; inferior border at level of foramen magnum
Other Factors Affecting Risk: HTN, skull base surgery, diabetes, chemotherapy, age, volume
Toxicity Endpoint and Rates: cranial neuropathies or brainstem necrosis
Recommended Dose-Volume Limits:
D1-10 cc <59 Gy
Dmax <64 Gy (point dose < 1cc)
SRS: Dmax < 12.5 Gy

Organ: Spinal cord
Authors: Kirkpatrick et al
Background: RT-induced myelopathy can result in pain, paresthesias, sensory deficits, paralysis and bowel/bladder incontinence. It rarely occurs less than 6 months after RT but usually w/in 3 years.
Contouring/Volume: precise cord definitions is not critical in conventional RT. For SRS: spinal cord +2-3 mm and extend critical organ volume above and below the target volume by 6 mm.
Other Factors Affecting Risk: age, intrathecal chemotherapy
Toxicity Endpoint and Rates: myelopathy, grade 2 or higher
Recommended Dose-Volume Limits:
Fractionated: full cord cross section; Rate <1% → 54 Gy; Rate <10% → 61 Gy
SRS: Rate <1% single fraction <13 Gy; Rate <1% hypofractionated (3 fractions) <20 Gy
For reirradiation of the full cord at 2 Gy per day cord tolerance increases at least 25% 6 months after initial course.
When only irradiating a partial circumference of the cord the dose may be increased but studies are needed to determine recommended tolerance.
Organ: Liver
Authors: Pan et al
Background: Liver often gets incidental RT when treating abdominal tumors. Need to be protected because has important synthetic and catabolic functions for body.
Contouring/Volumes: Easy to identify on CT. Left border can be indistinct against heart. Can move 2cm with breathing, which is minimized with compression, shallow breathing. Need to take motion into account for SBRT.
Other Factors Affecting Risk: underlying liver disease (cirrhosis, HBV, HCV)
Toxicity Endpoint and Rates: classic RILD, non-classic RILD
Recommended Dose-Volume Limits:
Conv Fx for Partial liver: Mean liver dose <28Gy in 2 Gy for primary liver cancers. Mean liver <32Gy in 2Gy for mets.
SBRT for primary liver CA(3-6 fx) Mean liver dose <13Gy for 3fx, <18Gy for 6 fx
SBRT for mets (3-6 fx) Mean liver dose <15Gy in 3 fx, <20Gy in 6 fx
SBRT for primary liver CA in Child Pugh B: Mean liver dose <6Gy in 4-6Gy fx
≥700cc of normal liver receives ≤15Gy in 3-5fx

Organ: Stomach/Small Bowel
Authors: Kavanaugh et al
Background: Stomach produces gastric acid to digest food; SB absorbs fats, AAs, lipids. These receive incidental dose during abdominal and pelvic RT.
Contouring/Volumes: Sim with contrast. Avoid large meals/carbonation prior to sim. Must segment contrast out when contouring. Use belly board to reduce SB volume.
Other Factors Affecting Risk: Prior surgery/adohesions
Toxicity Endpoint and Rates: During tx: N/V. Days to weeks: ulceration/bleeding/diarrhea Chronic: obstruction, dyspepsia, ulceration
Recommended Dose-Volume Limits:
For stomach: V22.5<4% or 5cc, with max point dose <30Gy for 3 fx SBRT.
For SB: V15<120cc if drawing bowel loops. V45<195cc if peritoneal cavity contoured.
For SB SBRT: V12.5<30cc in single fx, max point dose <30Gy in 3-5fx SBRT

Organ: Kidney
Authors: Dawson et al
Background: Kidneys are dose-limiting for much of GI, GYN, abdominal malignancies, and TBI. They need to be protected b/c their function of waste metabolism is so important.
Contouring/Volumes: kidney parenchyma, not collecting system. Can move inferiorly up to 7cm. Also kidney shape changes from supine to upright position. Important e.g.- in blocks for TBI.
Other Factors Affecting Risk: chemo (cis), underlying comorbidities (DM, HTN)
Toxicity Endpoint and Rates: acute TBI: HUS, MAHA, thrombocytopenia Acute: ↓GFR, ↑β2 microglobulin. Chronic: malignant HTN, ↑ creatinine, anemia, renal failure
Recommended Dose-Volume Limits:
Whole kidney: Bilateral kidneys TBI: Mean<10Gy. Bilateral kidney, non-TBI: 18Gy.
Partial kidney: Bilateral: Mean<18Gy; V28<20%, V23<30%, V20<32% V12<55%
If mean dose to 1 kidney >18Gy, then keep other kidney V6<30%
Organ: Urinary bladder
Authors: Viswanathan, et al
Background: RT to the pelvis leads to bladder injury
Contouring/Volumes: Contour either entire bladder (with urine) or bladder wall alone (excluding urine) on CT, average contour volume highly variable
Other Factors Affecting Risk: infection, increasing age, surgery, chemotherapy/hormone therapy, EBRT >50 Gy, higher dose per fraction, acute urinary toxicity, black race, smoking history, BMI >30kg/m2, anticoagulation medications (hematuria), brachytherapy, teletherapy, bladder motion
Toxicity Endpoint and Rates: Grade ≥ 3 late RTOG, <6%
Recommended Dose-Volume Limits:
Whole bladder
Conv Fx
Dmax < 65
V65 ≤ 50%
V70 ≤ 35%
V75 ≤ 25%
V80 ≤ 15%
Based on RTOG 0415 recommendations for prostate cancer treatment

Organ: Rectum
Authors: Michalski, et al
Background: Acute rectal injury: softer/diarrhea-like stools, pain, sense of rectal distention w cramping, frequency, superficial ulceration → bleeding. Late rectal injury: stricture, diminished rectal compliance/decreased storage capacity → small/frequent BMs, injury to anal musculature → fecal incontinence or stricture
Contouring/Volumes: Contour as a solid organ including contents
By anatomic markers
Superior limit: rectosigmoid flexure
Inferior limit: level of anal verge, at or 2 cm below ischial tuberosities, above the anus (caudal 3 cm of intestine)
By rectal length
Superior limit: 1cm above the target volume
Inferior limit: 1 cm below the target volume
Other Factors Affecting Risk: Diabetes mellitus, hemorrhoids, IBD, advanced age, androgen deprivation therapy, rectum size, prior abdominal surgery, severe acute rectal toxicity
Toxicity Endpoint and Rates: Bleeding 5%, Frequency 6%, Fecal incontinence 7%
Recommended Dose-Volume Limits:
Conv Fx
V50 < 50%
V60 < 35%
V65 < 25%
V70 < 20%
V75 < 15%

Organ: Penile bulb
Authors: Roach, et al
Background: RT-associated erectile dysfunction often evolves gradually and is difficult to differentiate from ED related to other causes. The penile bulb itself is not part of the erectile apparatus but is considered an anatomic surrogate for periprostatic tissue likely to receive high doses of RT
Contouring/Volumes: T2-weighted MR: an oval-shaped, hyperintense midline structure
Axial CT: bounded by the crura, corpora spongiosum, and levator ani
UCSF: most proximal portion of the penis sitting immediately caudal to the prostate
Other Factors Affecting Risk: baseline pretreatment ED, diabetes, smoking history, hypertension
Toxicity Endpoint and Rates: Self-reported severe ED rate ~<35%
Recommended Dose-Volume Limits:
Conv Fx
Mean dose to 95% of gland <50
D90 <50
D60-70 <70