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Title: Flap Delineation Guidelines in Postoperative Head and Neck Radiation Therapy for head and neck cancers

Running title: head and neck flap delineation guidelines

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Abstract

Introduction

Reconstructive surgery in head and neck cancers frequently involves the use of autologous flaps to improve functional outcomes. However, the literature suggests that postoperative radiotherapy deteriorates functional outcomes due to flap atrophy and fibrosis. Data on patterns of relapse after postoperative radiotherapy with a flap are lacking, resulting in heterogeneous delineation of postoperative clinical target volumes (CTV). Flap delineation is unusual in routine practice and there are no guidelines on how to delineate flaps. Therefore, we aim to propose a guideline for flap delineation in head and neck cancers to assess dose-effects more accurately with respect to flaps.

Material and methods

Common flaps were selected. They were delineated by radiation oncologists and head and neck surgeons based on operative reports, on contrast-enhanced planning CTs and checked by a radiologist. Each flap was divided into its vascular pedicle and its soft tissue components (fat, fascia/ muscle, skin, bone).

Results

Delineation (body and pedicle) of Facial Artery Musculo-Mucosal, pectoralis, radial forearm, anterolateral thigh, fibula and scapula flaps was performed. Based on information provided in operative reports, i.e. tissue components, size and location, flaps can be identified. The various tissue components of each flap can be individualized to facilitate the delineation.

Conclusion

This atlas could serve as a guide for the delineation of flaps and may serve to conduct studies evaluating dose-effects, geometric patterns of failure or functional outcomes after reconstructive surgery. Changes in postoperative CTV definitions might be needed to improve risk / benefit ratio in the future based on surgery-induced changes.

Keywords: Head and neck cancer, radiotherapy, postoperative, reconstructive surgery, flap, delineation

Introduction

Head and neck cancer patients frequently require surgery and postoperative radiotherapy. Whenever tumor resection involves large tissue volumes, reconstructive surgery is usually needed. Reconstructive surgery frequently involves the use of autologous flaps, placed at the tumour bed to compensate for the loss of substance [1, 2]. Autologous flaps are units of tissue that are harvested at a donor site and transferred to a recipient site in a same individual. Autologous flaps can be made of muscle, fascia, fat, skin or bone tissue, and may carry their own blood supply, depending on the recipient site's needs and constraints. The choice of the flap can be based on the six C's rule to account for the properties of flaps: circulation, composition, contiguity, conformation, construction, and conditioning [3, 4]. Flaps are continuously evolving to become more versatile to improve functional outcomes and to yield high fidelity to the native tissue in such aspects as sensitivity [5]. They were initially used in the salvage setting in irradiated tissues but are now increasingly used upfront. They are present in about half the patients undergoing postoperative radiotherapy, with wide variations between different tumor sites and surgical teams.

Target volumes have been extensively defined and evaluated for tumors undergoing definitive radiotherapy [6]. In contrast, postoperative target volumes have rarely been specifically described [7-9]. Moreover, transformations in head and neck cancer surgery have yet unevaluated consequences on the way to perform radiotherapy [2, 10, 11]. The postoperative clinical target volume (CTV of the primary) is defined as a volume of tissue that contains a macroscopic or probabilistic subclinical tumor volume, at risk for tumor recurrence. Although it is estimated that over $\frac{3}{4}$ of oral cavity patients and a majority of oropharyngeal cancer patients [12], have a flap, current recommendations for the delineation of postoperative target volumes do not mention the substantial tissue changes that occur with a flap in the tumor bed [13]. Because the use of a flap is increasingly frequent not only for oral cavity and oropharyngeal tumors for all other tumor sites [2], refining postoperative CTV definitions seems important.

Postoperatively, the flap is expected to cover the resected mucosal surface and to be connected in depth and periphery to native tissues (tissue junction) [14]. Several reports suggest that radiotherapy has deleterious effects on flaps with respect to functional outcomes (dysphagia/swallowing, speech,

etc.) [15-20]. Further, opinions are highly contrasted with respect to the risk of relapse in a flap. Because a flap is an ectopic tissue taken at a distance from the tumour, it may not be at risk of tumor involvement, except for contiguous extension from tumor seeding at the tissue junction area between native tissues and the flap itself [14, 21]. The tissue-flap junction may be better identified using surgical clips [22]. Flap components might influence the risk of recurrence. Based on data in breast cancer patients, fat in a flap could promote tumor growth (unless such observations are due to confounding obesity-related or hormone-related issues) [23]. A monocentric pilot study showed that radiation oncologists included most of the flap in their CTV-T. Noteworthy, 81% of the body flap was indeed included in CTV-T (**Figure 1**), suggesting that flap borders were inaccurately identified during delineation [24]. Full flap inclusion in the CTV results in increased irradiated volumes (especially for large flaps), and subsequent risk of excess toxicities and worse functional outcomes [25-29].

Due to the lack of data on the flap-tissue junction being the only potential area of recurrence and because of the belief that flap irradiation could deteriorate functional outcomes, it could be important to report dose-effects accurately. However, flap delineation is unusual in routine practice and there are no specific guidelines [12]. Any study trying to investigate patterns of relapse or functional outcomes with respect to flap irradiation should be based on a standardized flap delineation protocol.

Standardizing flap delineation is critical to the analysis of relapse and toxicity patterns to further refine postoperative CTV definitions. The aim of this article is therefore to propose a delineation method for the main types of flaps currently encountered in head and neck cancers.

Material and methods

Imaging modalities for postoperative radiotherapy planning : considering that standard postoperative CT scans consist of 2-3mm slices, contrast-enhanced planning CT was chosen as the method of reference to delineate the flaps. Preoperative images (CT, MRI and/or TEP-CT) were coregistered with the postoperative planning CT to delineate the preoperative gross tumor volume (GTV), managing coregistration uncertainties as best as possible. Because clipping is not systematic among head and neck surgeons, clipping of the operative bed was not expected to select cases for delineation to illustrate a more general scenario.

Choice of flap and donor vessels to recipient anastomosis : typical postoperative planning CT of patients who underwent flap-based reconstructive surgery for head and neck cancer were selected among reconstructive procedures performed in 2019-2020. We also considered donor site morbidity and quality of recipient vessels along with diameters of donor versus recipient vessels. Selected soft tissue flaps included in the following atlas were a Facial Artery Musculo-Mucosal (FAMM) flap, a pectoralis flap, a radial forearm flap and an anterolateral thigh flap. Bone flaps included a fibula flap and a scapula flap **(Figure 2)**.

Results

The list of flaps cannot be comprehensive as this field is rapidly evolving, including the use of free-style flaps arising with advances in microsurgery and tissue transfer. The use of flaps also depends on team experience. So, we selected flaps that appeared to be performed quite frequently in most institutions performing reconstructive surgery. Reconstructive surgery integrates both the selection of the better flap for each reconstruction and the choice of recipient vessels, an essential pre and intraoperative step.

The recipient vessels are chosen so that the artery has a similar diameter as the donor artery, no or minor atherosclerosis, satisfying intraoperative flow, and suitable length for the flap pedicle and, of course, no tumor tissue. Vein selection is usually related to the anatomy of the pedicle and recipient vein available in the neck, with more interindividual variability than for arteries. In non-vessel-depleted necks, tributaries of the internal jugular vein are available in different diameters. Some surgeons prefer an end-to-end anastomosis with one of these branches -usually near the artery- and some other surgeons prefer an end-to-side anastomosis directly with the internal jugular vein. Artery and vein(s) should have parallel axis. Despite preoperative preparation, the choice of vessels requires a wise choice based on intraoperative findings. This is beyond the scope of the current article. Contrast-enhanced CT allows for the visualization of donor vessels arising from the flap to the recipient artery and vein.

The operative report is necessary to accurately locate the flap site and its components (**Figure 2**) based on their tissue densities, length and thickness after flap harvesting and reshaping. A standardized operative report should include the following information:

- Tumor resection step:
 - Type of surgical approach (transmandibular, bone resection, transoral or cervicofacial approaches, TransOral Robotic Surgery or laser-assisted surgery, endoscopic approaches, etc)
 - Macroscopic aspect of the tumour (size and location)
 - Relationship to adjacent structures assessed perioperatively.
 - Quality of resection (margins) and whether to perform an extemporaneous evaluation
 - Assessment of additional margins
- Flap harvesting :
 - Decision for type of flap
 - Accurate and comprehensive description of flap components: fat, muscle, fascia, skin or bone
 - Harvesting technique
 - On-site conformation, if needed
 - Operative complications (hemorrhage, nerve injury, other)
 - Length of pedicle (cm)
- Modelling and anastomosis
 - Description of recipient vascular tree and type of anastomosis
 - Nerve anastomosis and location
 - Description of mucosal/bone suture location (conformation).
 - In the case of a pedicled flap, indication of where the pivotal zone is located
- Description of perioperative complications if any (twist, stretch, necrosis, etc)

Flap delineation was performed on planning by radiation oncologists (JLG, JT, MG, AL, LG) and two head and neck surgeons (ALC, VB) on RayStation treatment planning software (RaySearch) v8 with verification by a radiologist (PYM). Bone is in the high range of -70-300 HU for spongy bone to 3000 HU for dense bone. Fat density is around -50 HU; soft tissue density varies between 0 and 70 HU. A

soft tissue window level (L35UH and W350 UH) was used for soft tissue flap delineation and was enlarged to bone density when needed. The delineation process was based on the operative report, to identify the type of flap, its components (fat, fascia, muscle, skin, bone), and the areas of vascular anastomoses. A direct comparison between the pre and postoperative CT was used to analyze postoperative tissue reshaping and tissue changes. Flaps can be indirectly identified by comparing, inferring a symmetry principle, them to native anatomy and by the loss of symmetry on post-operative CT-scan. In addition to axial and sagittal planes, coronal planes can be very useful for tumors of the oral cavity (tongue and floor of mouth) to distinguish the flap from native muscles. They can be distinguished from edema and fibrosis as they are made of different tissue components and are relatively well limited compared to edema and fibrosis.

Each flap was artificially divided into two parts: the pedicle, corresponding to the vascular structures for blood supply (vein and artery), and the flap body (fat, fascia/ muscle, skin, bone) used for tissue defect filling and corresponding to the surgical bed. This subdivision is anatomically visible on CT for free flaps but may be hard to distinguish for large pedicled flaps, such as the pectoral flap (**Figure 3**). For free flaps, the vascular pedicle is thin while the flap body is thick enough to fill the tissue loss; both are easily distinguished from one another. In case of pedicled flaps, the caudal limit of the flap's body (called flap in the manuscript) was defined as the caudal limit of the preoperative gross tumor volume (GTV) using pre-operative imaging (MRI, TEP-CT or CT) fused with the planning CT.

The flap body and its vascular pedicle (vein and artery together) were delineated independently. The most used recipient arteries are branches of the external carotid artery system, especially the thyroid superior, facial, and lingual arteries (**Figure 4**) and their associated veins or thyrolinguofacial trunk. They are roughly 1.5 cm above the large wing of the hyoid bone on the vascular axis. Anastomoses are occasionally performed with the external carotid artery (ECA) when smaller arteries are not adequate. In vessel-depleted necks, because of previous surgery or tumor infiltration of ECA, the transverse cervical artery may also be used. The vascular anastomosis and anatomic variations should be described in the operative report. For radiation oncologists, it may be useful to visualize the arterial anastomoses to avoid hot spots (high doses) (**Figure 4**).

Delineation (see below) was guided by knowledge of usual flap-specific components (fat, skin, fascia, muscle, bone).

The local pedicled rotational soft tissue (FAMM) is indicated in case of non-transfixing loss of substance from the floor of mouth, tongue or veil. This flap is pedicled on the facial artery and carries away the buccinator muscle and the mucosa of the inner face of the cheek. Venous drainage takes place through the veins of the buccal plexus and through the facial vein. The specimen usually measures a few centimetres at most in order to have a self-closing donor site if possible: the anterior limit should not be less than one centimetre from the labial commissure, the posterior limit should not exceed the orifice of the parotid duct. The flap is rotated into the resected area. In case of posterior reconstruction, the point of rotation of the flap could be more posterior, centered on the buccal artery and a buccinator branch of the facial artery (buccinator flap). Being thin and made of mucosa, it can be difficult to individualize from surrounding native tissues. As in figure 5a, the flap can be indirectly identified by comparing it to native anatomy and muscles of the mouth floor. The limits of the flap can be determined by comparing the density of the flap in relation to the surrounding tissue: the peripheral mucosa takes on the contrast at its surface, resulting in a higher density than the surrounding mucosa (periphery on axial CT slices). The thickness of this mucosa is usually about 5mm. In the center of this flap stands the buccinator muscle, which has a density around 50 HU. The sites where sutures were placed are usually specified in the operative report and are to be noted. In this example, the flap covers the bone part section that was removed and is sutured at the level of the mandibular symphysis. Medially, the mucosal membrane of the flap is connected to the ventral surface of the tongue. The deep part of the buccal floor is preserved.

The pectoralis flap is a regional pedicled muscular or musculocutaneous soft tissue flap. It can be performed in case of important loss of substance of pharyngeal, oropharyngeal, or cervical soft tissues. This flap is one of the safest and most easily made (**Figure 2**). Its main pedicle comes from the thoraco-acromial artery, which is a branch of the axillary artery, and starts at the upper edge of the small pectoral muscle. Harvesting is done while preserving the deep aponevrosis of the muscle, thus protecting the vessels. The pivotal point of the flap is at the level of the clavicle. Once lifted, the flap is transferred to the cervical recipient area through a subcutaneous supra-clavicular tunnel that should be wide enough

not to squeeze the pedicle. The flap length and its tissue components are harvested and modelled to conform to the size of the loss of substance. The flap is often about 9-10x6cm. The flap size is important to know as its pedicle length often makes it difficult to find its limits. The muscular part of the flap is harvested with the pre-pectoral fascia and associated skin. The cutaneous part of the flap is easy to determine, as it is associated with a fatty part, importance depending on the patient. Suture sites are to be specified in the operative report and vary substantially depending on primary tumor site. In figure 5b, sutures were placed to the prevertebral plane laterally, to the mucosa of the base of the tongue at the top, and to the esophageal mucosa at the bottom. A muscular plane is created between the flap and the suprahyoid muscles. This flap comes from the pectoral region, so the tunnel through which the flap is rotated is necessarily supraclavicular and subcutaneous. Pedicle delineation should be performed by comparing the anatomy to the contralateral anatomy. Finally, the pedicle can be artificially separated from the flap at the caudal level of the preoperative macroscopic tumor (**Figures 3, 5b**).

The fasciocutaneous radial forearm flap is a soft tissue free flap, harvested with its radial pedicle. It is used for extensive mucosal and musculo-mucosal repairs: floor of the mouth, hemi-tongue or veil, lateral oropharyngectomy, circumferential pharyngolaryngectomy... The skin paddle is taken from the distal part of the forearm, centred on the radial pedicle and the cephalic vein. This flap is almost exclusively composed of skin and fascia and is relatively thin. In depth, the flap is limited by the fascia, which forms a barrier to tumour extension. On the surface, the cutaneous part of the flap is sutured to the adjacent mucosa. The radial forearm flap (**figure 5c**) is made of fascia (not distinguished from underlying native tissues), fat (2-10 mm layer) and skin but does not contain muscle. The relatively hyperdense tissues of the skin and subcutaneous tissues are subsequently quite thin and located on the mucosal side of the flap. In figure 5c, the operative report described a 6.5x5.5cm skin flap, sutured with the mucous plane of the oropharynx. The fascia is oriented toward the anastomotic deep-seated area and is not visible. Due to absence of muscle in this flap, delineation is facilitated by tissues of lower density corresponding to its fatty elements in contrast to surrounding tissues. In figure 5c, the flap was placed at the level of the loss of substance and sutured at the bottom with the floor of the mouth and at the top with the ventral side of the tongue.

The soft tissue anterolateral thigh (ALT) flap is quite versatile as it can be shaped to convex anatomy and its size can vary substantially. Due to its versatility and minimal morbidity at the donor site, it is increasingly used. One of its major advantages is its minimal donor site morbidity. It mostly consists of fat and skin and has numerous perforating arteries. This flap is not composed of muscle. Therefore, it can be easily differentiated from adjacent tissues, which are largely composed of muscle. Its hypodense central fatty component is well identified. The size of the cutaneous part of the flap should be in the operative report: in Figure 5d, it measured 8x6cm. The underlying subcutaneous fat tissue layer, which can be used to delineate the deep portion of the flap, was 2-3 cm thick at its maximum. The anatomical relationship of the flap should be indicated in the operative report, and are, in **figure 5d**, the posterior pharyngeal wall posteriorly and the mucosa of the oropharynx anteriorly.

The fibula flap is the main composite bone flap used in head and neck cancer bone reconstructions. It provides the largest amount of bone and the longest pedicle length. Its vascularisation is double: interosseous and segmental through perforators, which allows osteotomies to be performed. It can be harvested as an osteo-cutaneous flap or a bone flap without skin. It is easily spotted by the osseous component and the titanium plate. The skin paddle usually covers the bone part and rebuilds the mucosal defect. The fatty part is very thin or absent. Delineation of a fibula flap can be complex due to the various components and to frequent addition of a titanium plaque or other implanted materials. The bony part can be quite easily identified due to disruption of the native bony segment and has similar thickness as the mandible. Moreover, fatty tissues surround the bony segment. In **figure 5e**, the operative report indicated that the bone sample had been taken from the medial part of the fibula and measured 5cm. A thin muscle flap was harvested along the entire length of the bone paddle and can be measured at around 50 HU. The skin sample was approximately 7cm long. It was sutured to the floor of mouth, to the intermaxillary commissure and to the left lateral oropharynx, as well as to the lingual junction zone.

The scapula bone flap can be harvested in simple or composite form (bone, muscle, and skin). The main arterial pedicle is the circumflex scapular artery. It provides various advantages, such as a diversity of

available tissues (two parts of bone, two independent skin paddles, three independent muscle paddles) that are independent and very mobile. It is used in complex reconstructions with large defects of different tissues. The scapula flap provides a relatively large flat bone and is surrounded by fat (hypodense) and muscle (more homogenous moderate density compared to mucosae). Operative reports are critical due to the variability of tissue harvesting and type of reconstruction. In **figure 5f**, the scapula bone flap measured 9cm in length and 2cm in height and was easily recognizable because fixed with plates and screws in the mandible. In this patient, bone was harvested with a muscle and skin flap, each measuring 3cm in length. The cutaneous edges were sutured to the jugular mucosa. Suture sites can be distinguished by comparison with the contralateral side.

Discussion

Standardization in the way to delineate flaps is warranted to assess both flap dose effects with respect to functional outcomes and geometric patterns of failure and whether changes in postoperative CTV definitions are needed. Thus, guidelines on how to contour flaps are warranted. This atlas is a first initiative and is being used in the multicentric “Xflap” study (registered as a non interventional study under GDPR-compliant CNIL/MR004 2214228 v0 number on July 3rd, 2019). Flap body (i.e. flap) and pedicle were independently delineated. It was indeed assumed, considering its components (fat, muscle, fascia, and skin in particular) that the flap body would have parallel architecture and could be damaged if receiving high mean dose radiotherapy. Such irradiation might deteriorate functional outcomes [25]. This is yet a relatively unexplored area and fat atrophy is also observed after surgery alone [30]. In contrast, vessels were assumed to behave as serial organs and could be damaged by hot spots, especially after microvascular sutures. This could theoretically lead to necrosis with subsequent flap loss. However, this does not seem to be the case in the current literature. In contrast, it is crucial for radiation oncologists to understand the mechanical details and 3D geometry of flaps to minimize risk for marginal misses. This is a major dilemma for the radiation oncology field because radiation oncologists are naturally inclined to view any abnormal tissue as a "target". Residents and non-head and neck radiation oncology specialists may even contour the body of a head and neck flap as a high-risk tumor volume, while completely missing the recipient bed. At the very least, a radiation oncologist should confer directly

with the surgeon to truly understand the surgical bed and locations of high-risk margins. This atlas does not prevent from considering a learning curve for each radiation oncologist. Delineation can be quite quick provided that the operative report is well documented. Delineation of the pedicle does not need to be extremely accurate; the aim is rather to define a 1.5cm zone where hot spots may be avoided, in the inverse planning optimization step. In the absence of data in favor of irradiation of either the whole flap body or the tissue-flap junction only, current practice should not be modified and this atlas should only serve to better assess the patterns of failure relative to the flap and the dose it has received (either tumoricidal or not)[21]. It should be noted that a 6mm-wide flap area defined from the surgical clips was defined by Bitterman without formal operative specimens [22]. Microscopic tumor extensions are rather around 10mm and may be as wide as 20mm [6, 31, 32].

The therapeutic implication is that if lack of or low dose irradiation to the flap body is not associated with a higher risk of local failure than when irradiating the whole flap body at a tumoricidal dose, toxicity may be decreased by irradiating the tissue-flap junction only [33]. Previous studies are limited in terms of accurate definition of flap delineation. Cho et al evaluated in-flap relapses without a formal flap reconstruction step on imaging [21].

From FAMM to pectoralis flaps, flap components and size vary considerably. While it seems that radiation-induced necrosis is exceptional regardless of flap vascularization, either free or pedicled, it is yet uncertain whether tissue components (**Figure 2**) could influence outcomes. It might be expected that large musculocutaneous will induce fibrosis and fat-dominant flaps may become atrophic. Bone flaps may also behave differently with uncertainties of the risk of osteoradionecrosis in relation to dose absorption in the osseous junction areas. However, formal dose-effect studies with objective assessment of complications and standardized measurement of functional outcomes are warranted to correlate dose to the flap, volume of flap irradiated and functional outcomes. Moreover, feasibility of flap sparing (to only irradiate the junction area) using dose-painting IMRT is inherently related to flap size. While flap sparing may be easily performed with pectoralis flaps, it will be unlikely with a FAMM, due to its small thickness. It is however important to address the two questions of the probability of microscopic tumor spread on one hand and the technical feasibility of flap sparing on the other hand.

Non-treatment issues associated with flap loss or alteration, such as cardiovascular comorbidities including hypertension, diabetes, coagulopathies and habitus such as tobacco consumption should be cataloged carefully in any prospective study; and argue for holistic care for head and neck cancer patients.

Overall, flap-specific expertise is critical in reconstructive surgery. Flap healing is usually awaited before patients are referred to radiation oncologists. Because delaying postoperative radiotherapy over 42 days can be deleterious in terms of oncologic outcomes. Similarly, flap necrosis often occurs immediately after surgery rather than after radiotherapy. Additionally, flap atrophy may occur independently of radiotherapy and this should be addressed as a confounding factor when evaluating post radiotherapy outcomes.

Potential limits of the proposed atlas are inherently related to the objective of keeping it practical and feasible based on a minimal imaging dataset available in routine practice. Others, such as Bittermann et al., defined a more precise tissue-flap junction using clips, however without strong level of evidence for their definition of the junction area [14]. Clips are inconsistently used across surgical teams (ongoing survey, data not shown). They are mainly used at vascular anastomoses. They may be used to mark the flap-tissue junction or to mark dubious resection margins. Adding clips to better define the target in the postoperative setting with a flap requires standardized surgical training and close radiosurgical collaboration : this is the focus of a future interventional study, where the current atlas will be used. Accuracy may be improved with millimetric CT slice thickness, instead of 2-3 mm thick slices. Similarly, biphasic sequences (arterial and venous + soft tissue acquisition times) should be favored to better distinguish native surrounding tissues from the flap skin and vessels. This is particularly critical in patients with low fat mass and for assessment of early complications of flap surgeries such as necrosis. Postoperative MRI currently has no indication in routine practice unless residual macroscopic tumor is suspected. However, fat, skin, and muscle are better discerned with MRI than CT, thus postoperative MRI could achieve better performance than CT to help distinguish the flap from surrounding native tissues (data not shown).

Reconstructive surgery with flaps may significantly change postoperative tissue configuration and may affect the patterns of failure. Flap delineation integration in routine practice might be used to assess dose-effects and might ultimately lead to changes of postoperative CTV definitions. Different flaps may be chosen based on loss of substance following tumor resection, donor comorbidities and functional expectations from flaps. The various tissue components of each flap can be individualized to facilitate the delineation. This atlas could serve as a guide for the delineation of flaps and may serve to conduct studies assessing postoperative patterns of spread, failure, and functional outcomes after reconstructive surgery.

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Figure titles and legends

Figure 1: Inaccurate flap delineation with uncertainties on whether the whole flap body should be in the CTV and how to delineate the flap.

Legend: In yellow, part of flap included in the CTV; in blue, CTV not including the flap ; in red, flap not included in the CTV

Figure 2: common flaps and their tissue components.

Legend: HU Hounsfield units. Black line: fascia

Figure 3: flap body and identification of the pedicle on axial views and 3D; left: pedicled flap and right: free flap

Figure 4: areas of arterial anastomosis.

Legend: A-C: volume rendering angioCT parasagittal views, A'-C': axial contrast-enhanced CT views. A : facial artery in green (submandibular gland usually removed with facial artery anastomosis in this area), A' : facial artery passing behind submandibular gland. B and B': superior thyroid artery (level of anastomosis may be a few millimeters below caudally). C and C': lingual artery (anastomosis is behind the plane of the base of tongue). Green lines for arteries from bifurcation with carotid to termination, white arrow: usual site of anastomosis (with millimetric positional variations along the artery). D: white dashed lines: 1.5cm wide band below the mandibular angle to mid mandible anteriorly and anteriorly of the carotid roughly corresponding to likely areas of anastomoses. D': 1.5 cm wide band extended from the submandibular gland to mid mandible anteriorly and anteriorly of the internal carotid and extending to the posterior edge of the submandibular gland

Figure 5a: Facial Artery Musculo-Mucosal flap (FAMM)

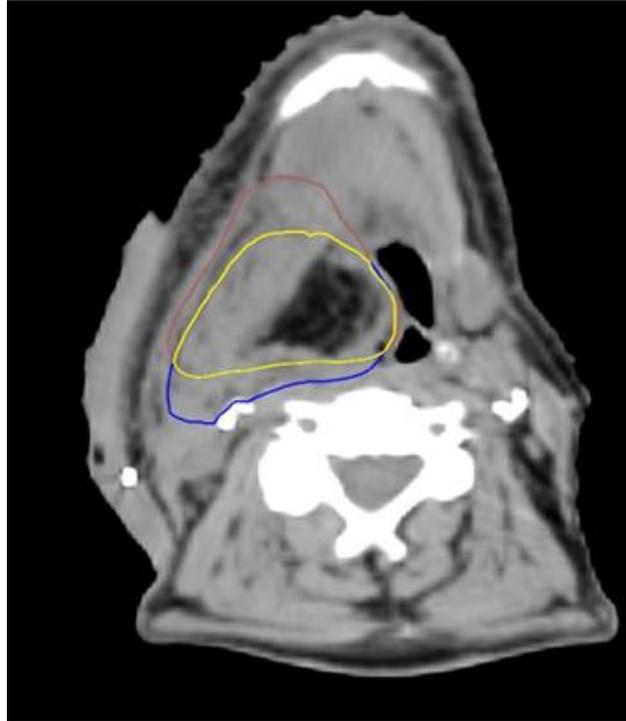
Figure 5b: pectoralis flap (following circumferential pharyngolaryngectomy)

Figure 5c: Radial forearm flap

Figure 5d: Anterolateral thigh flap

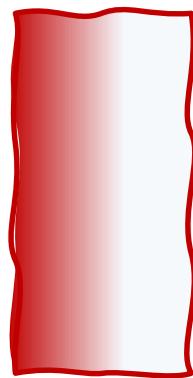
Figure 5e: fibula flap

Figure 5f: scapula flap (posterior view)



Deep native tissue margin

Mucosal surface *



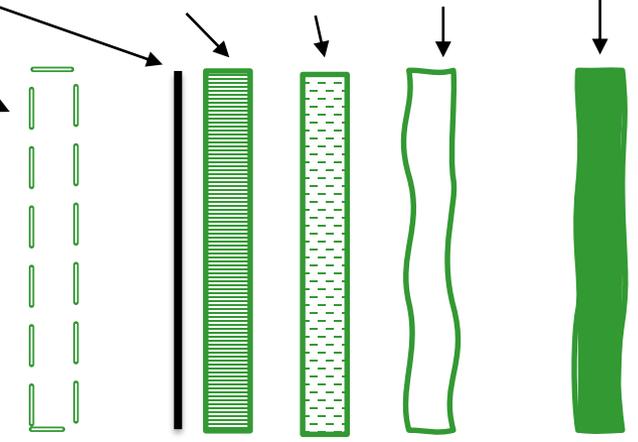
HU 3000-0

70-0

-40,-140

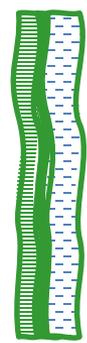
bone fascia muscle mucosa skin fat

Deep flap suture (depth)



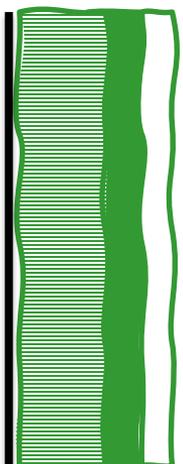
Surface *

FAMM Pectoralis Radial forearm AL thigh Fibula Scapula



*

depth



*

depth



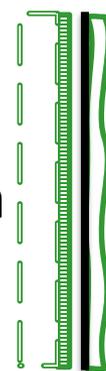
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depth



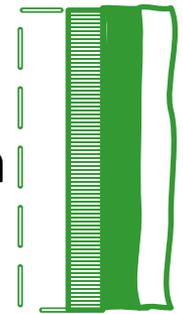
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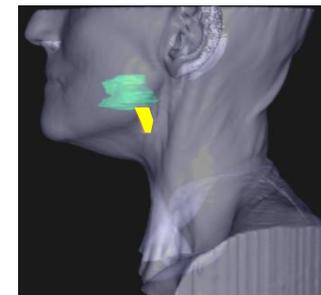
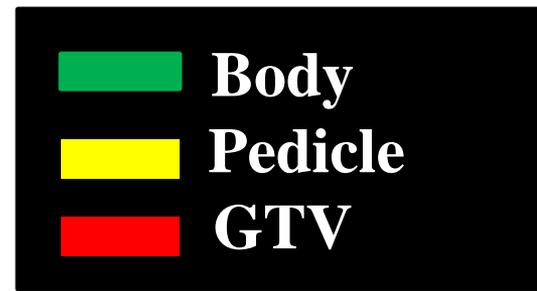
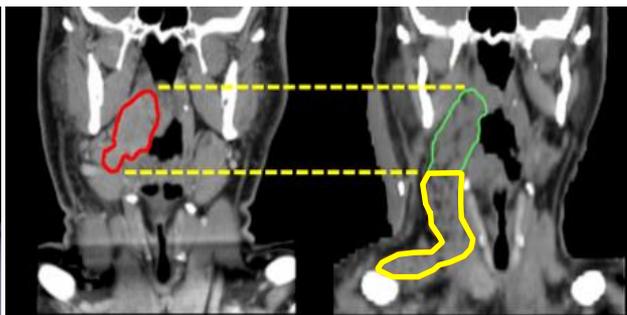
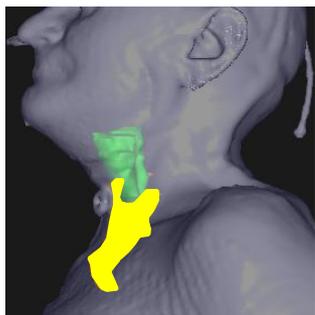
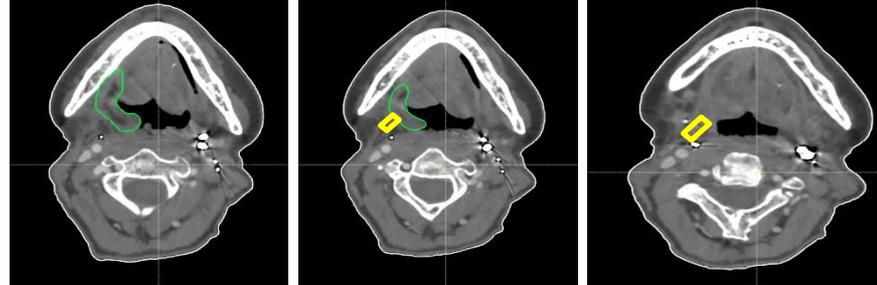
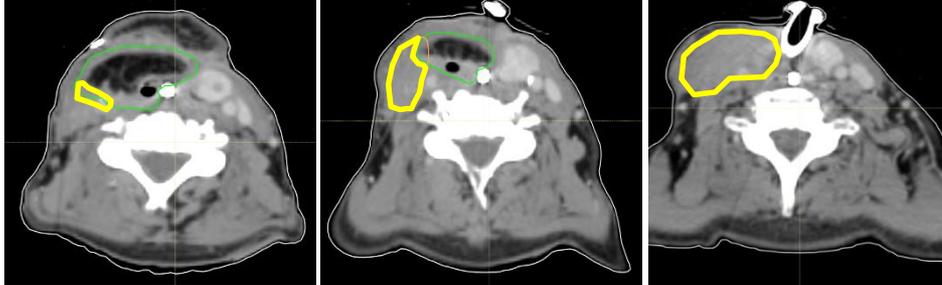


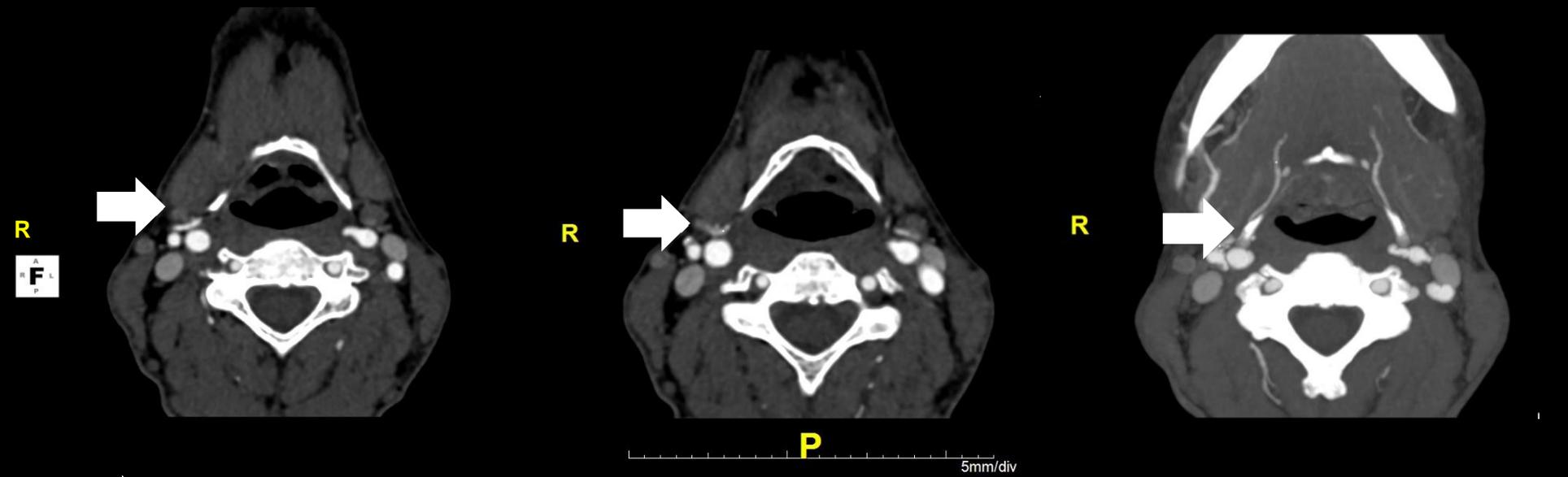
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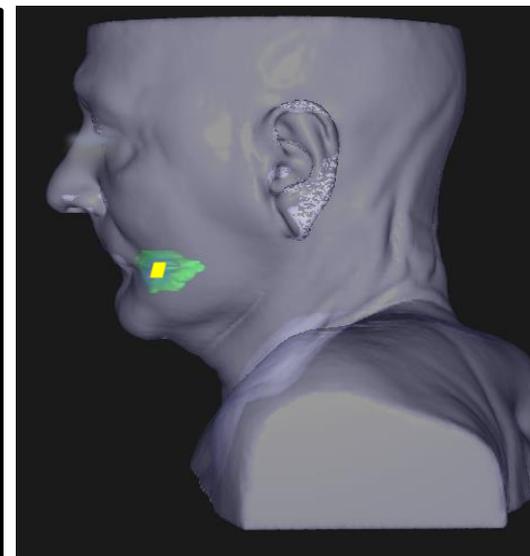
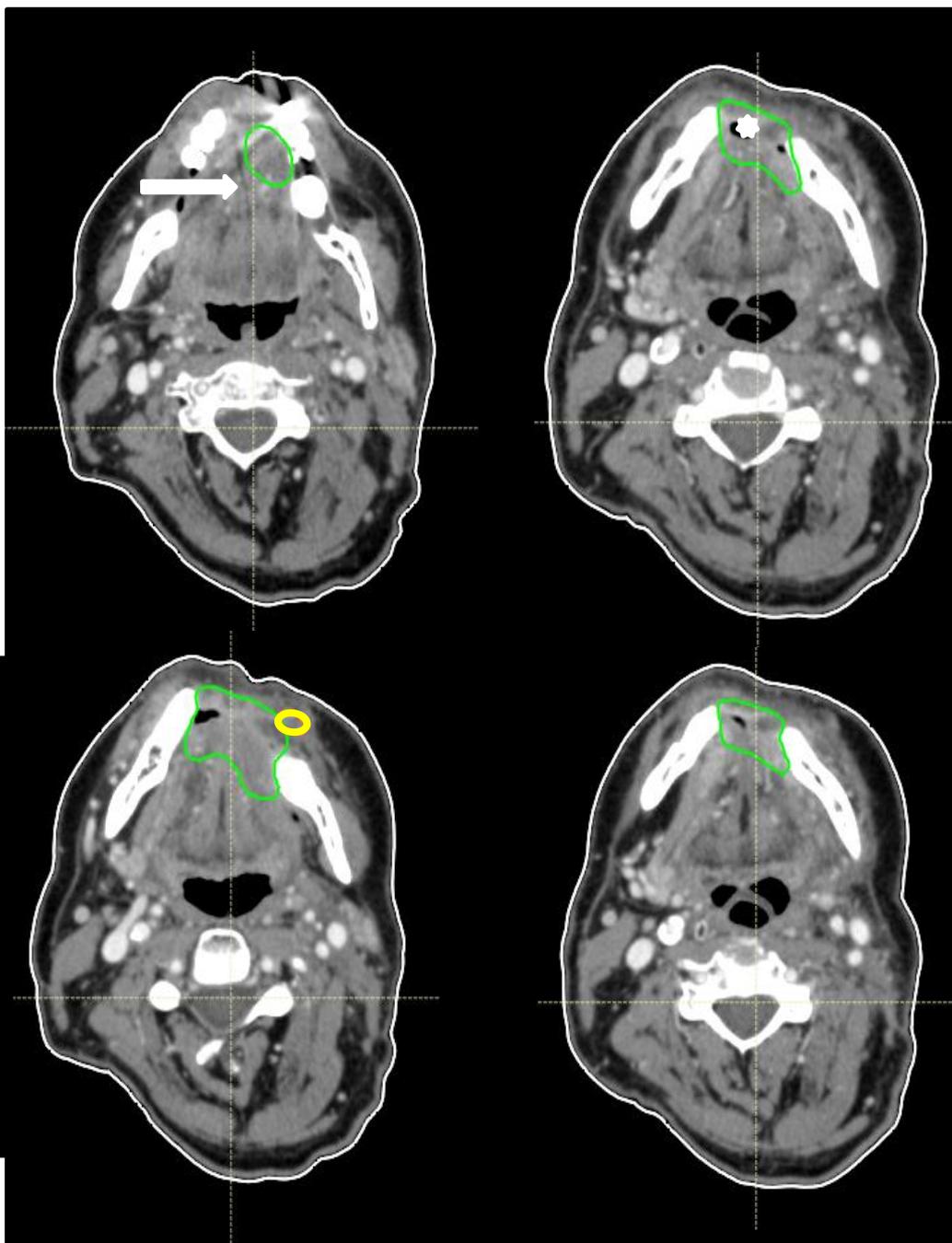
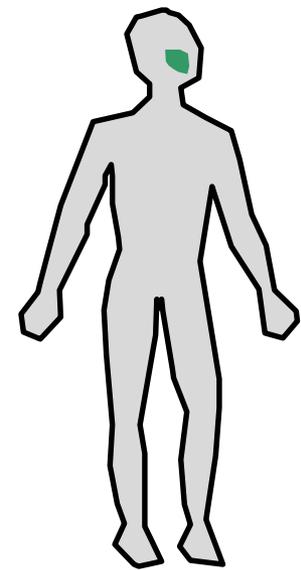
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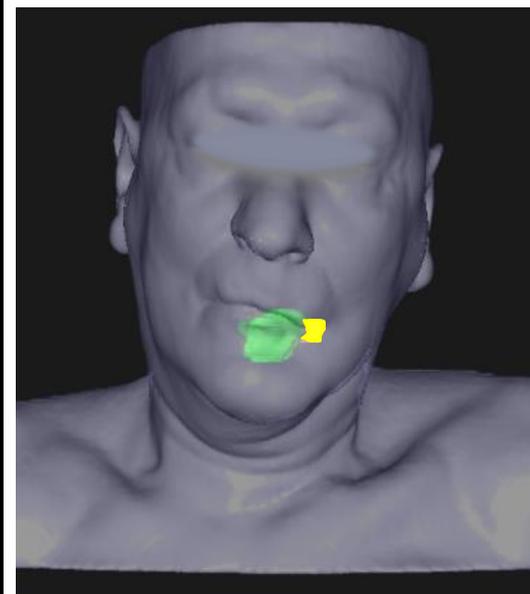
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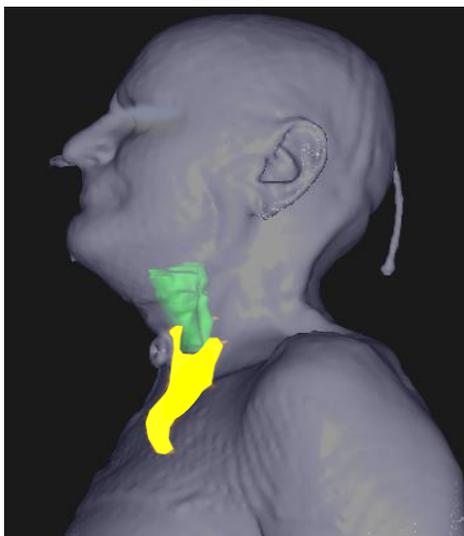
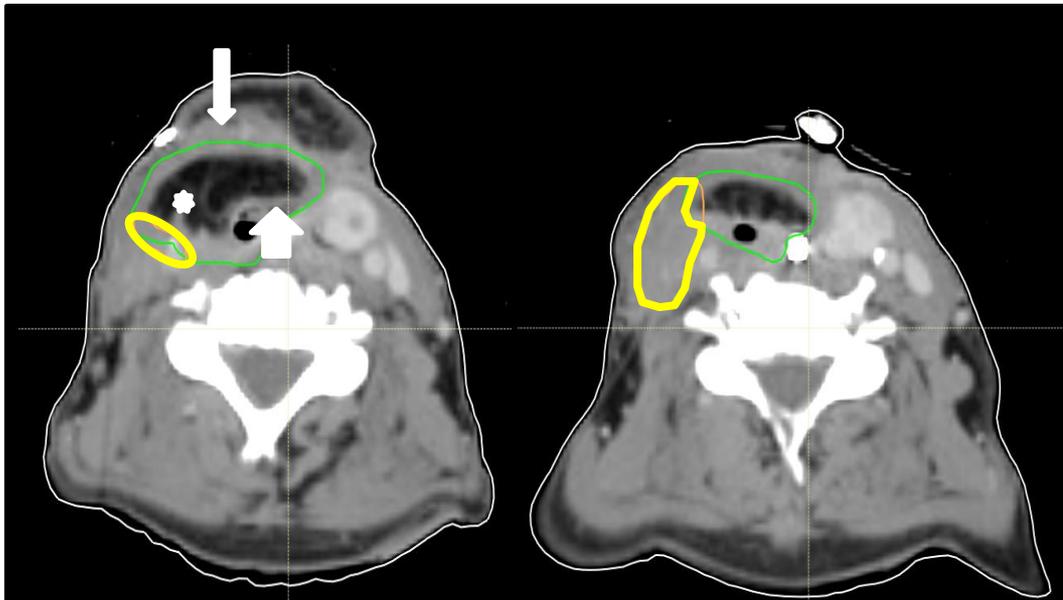
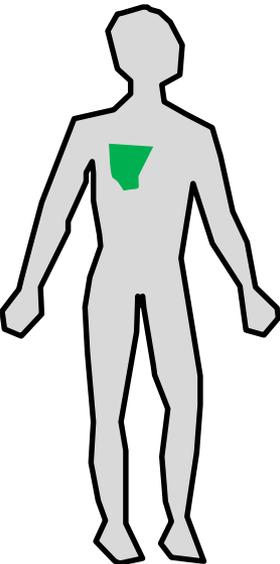




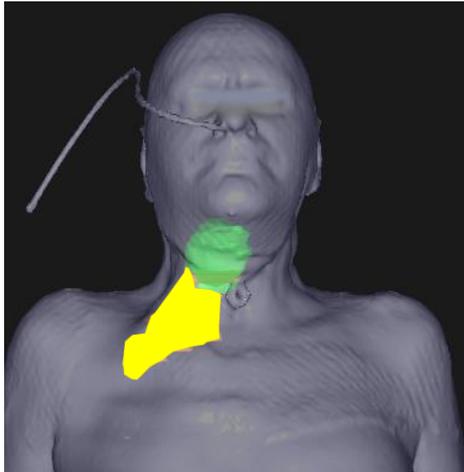
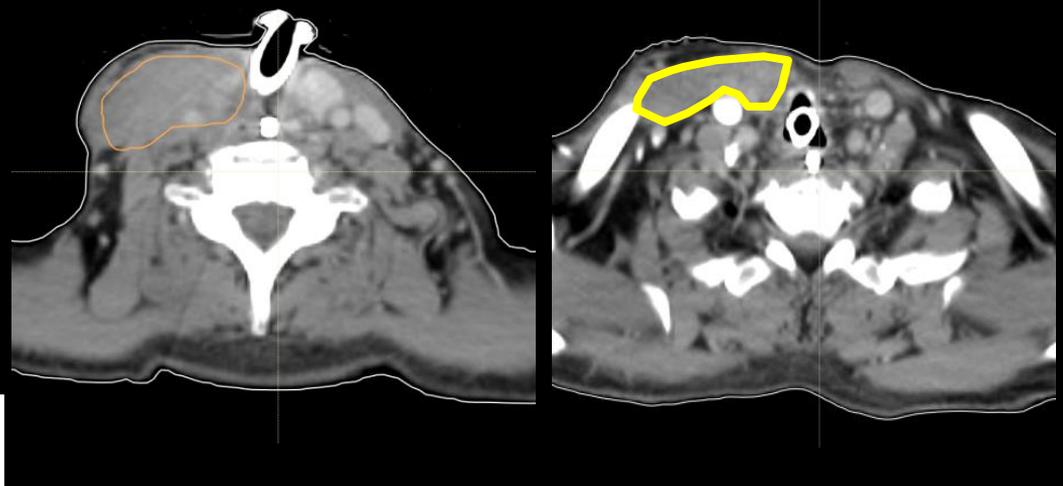


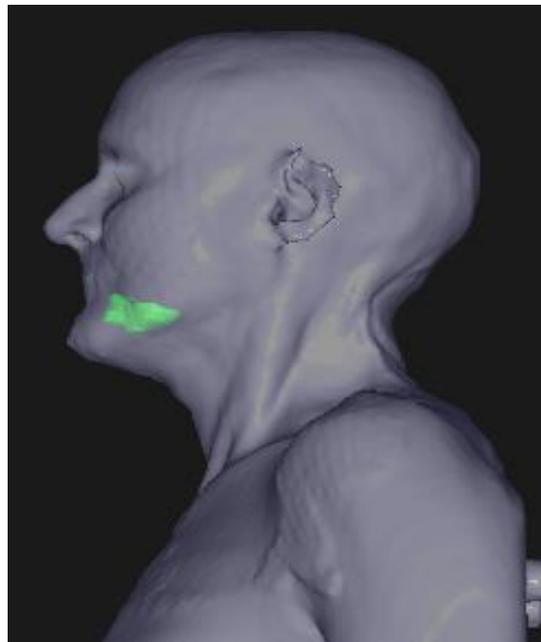
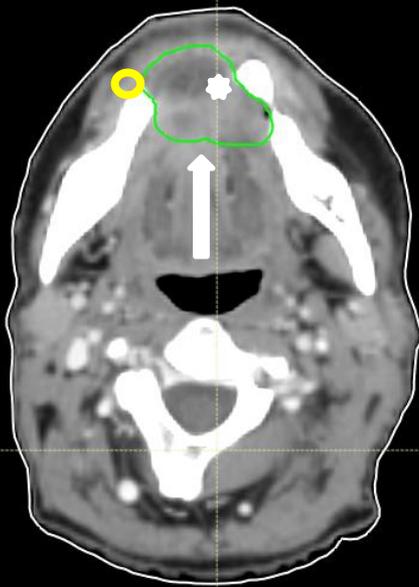
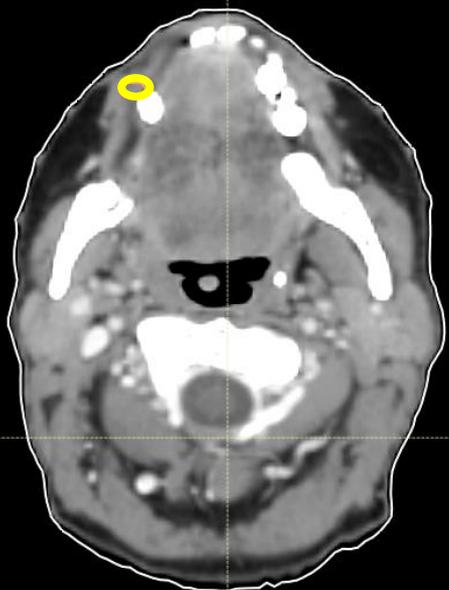
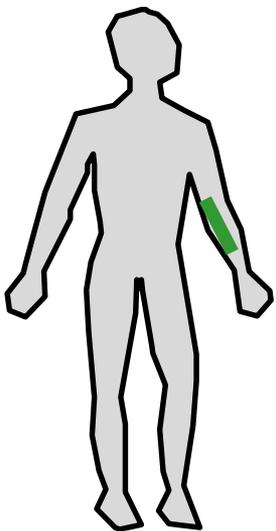
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-  **Fascia**
-  **Fat**



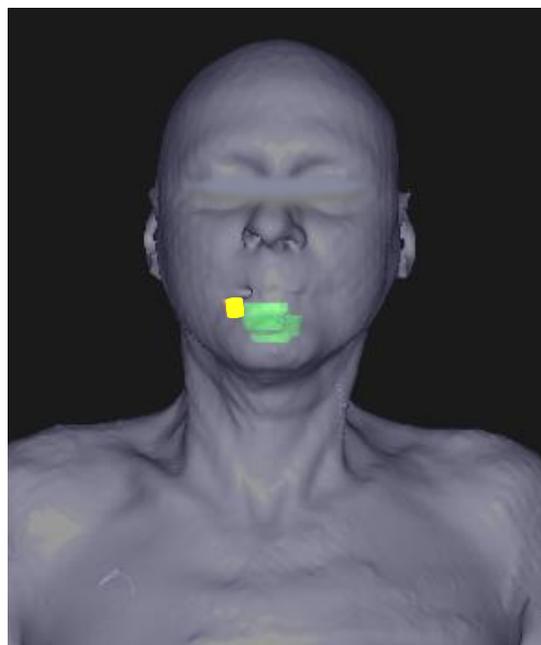
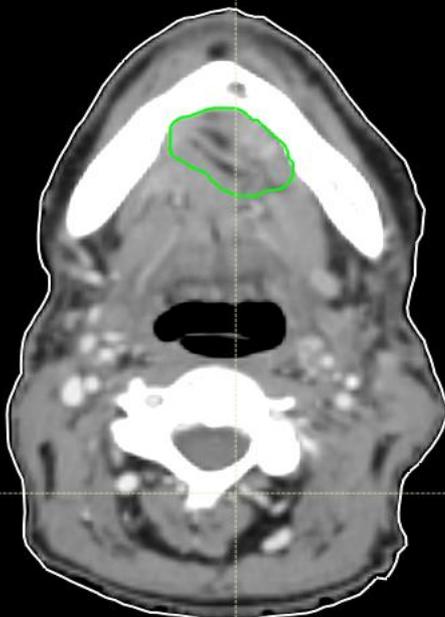
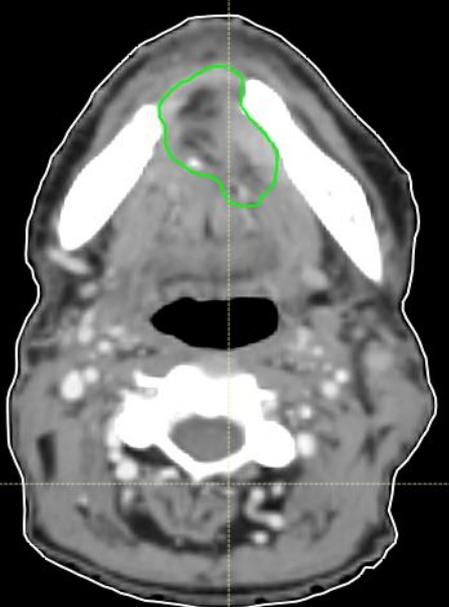


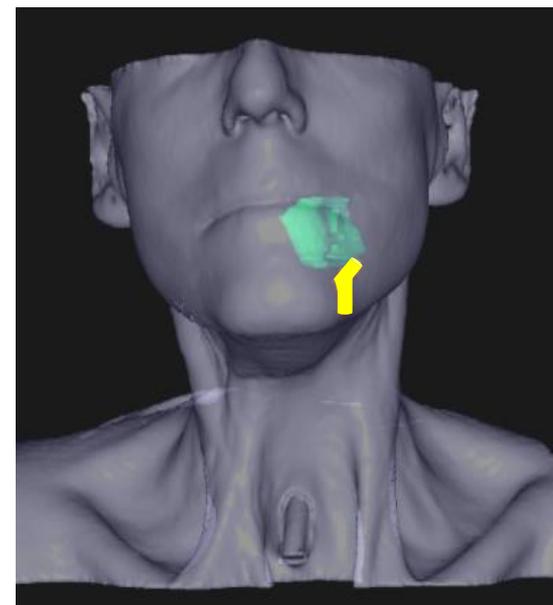
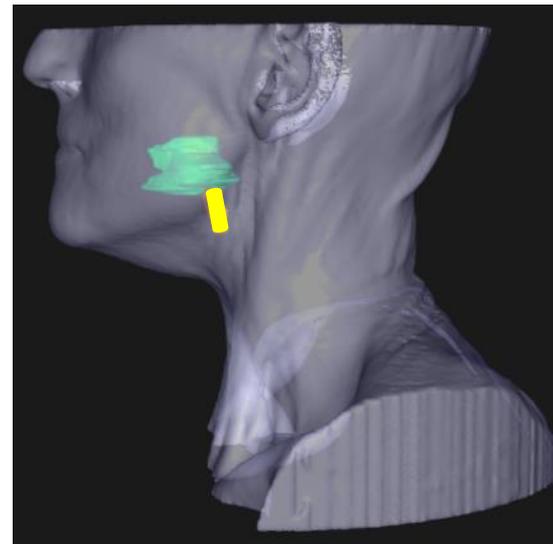
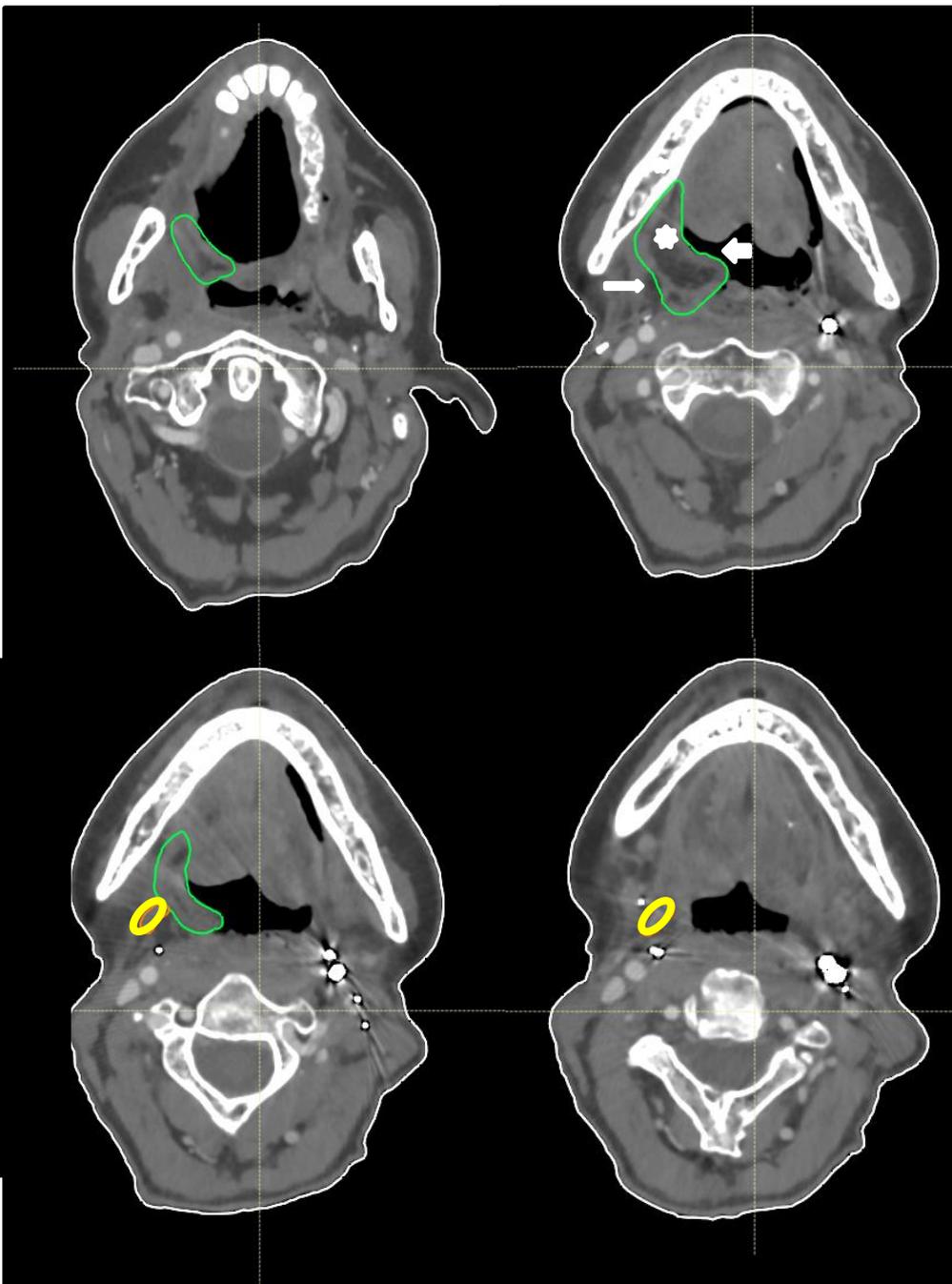
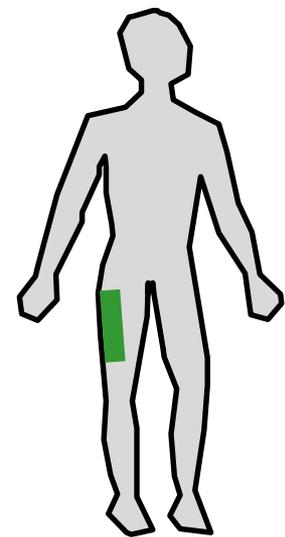
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-  **Skin**
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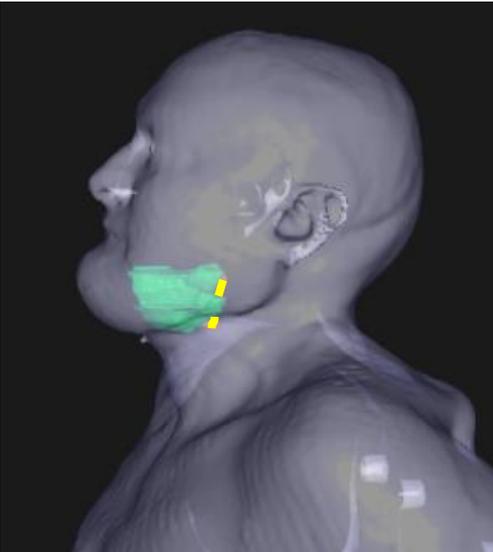
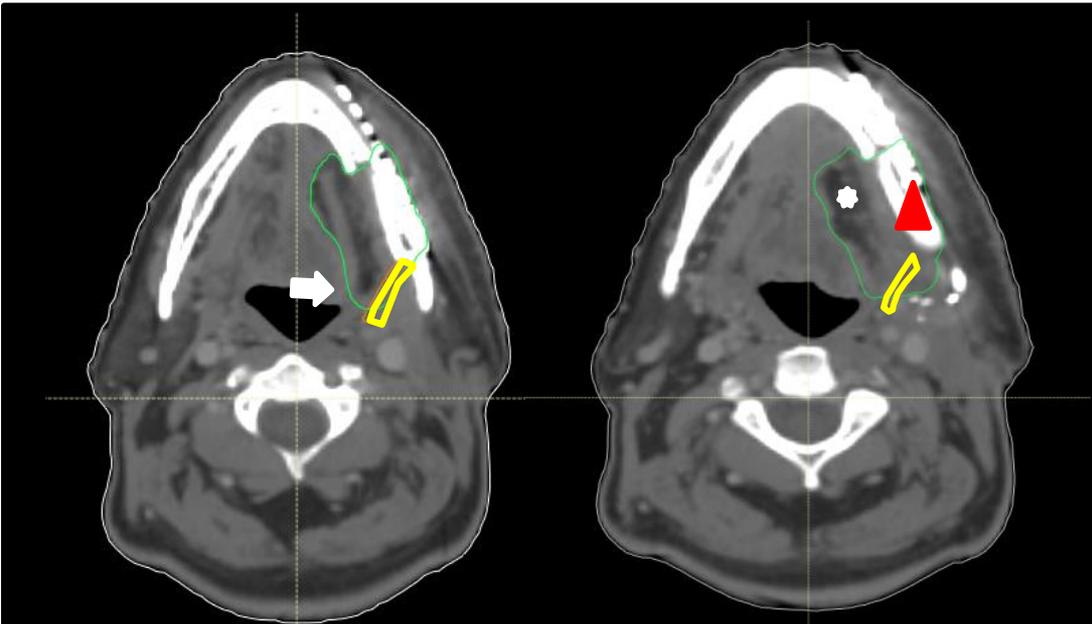
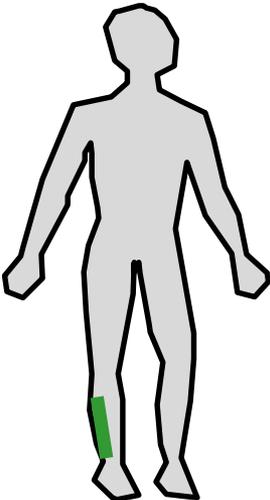


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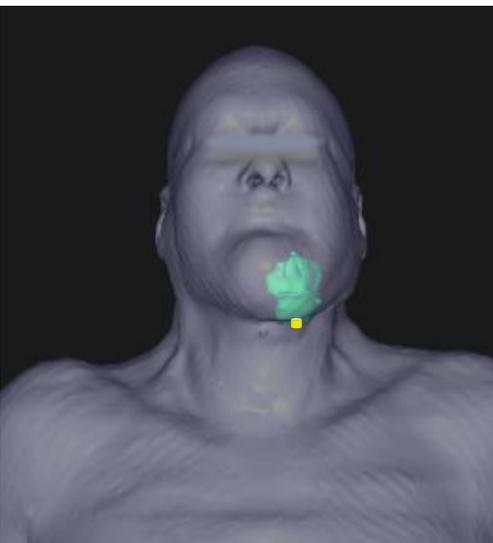
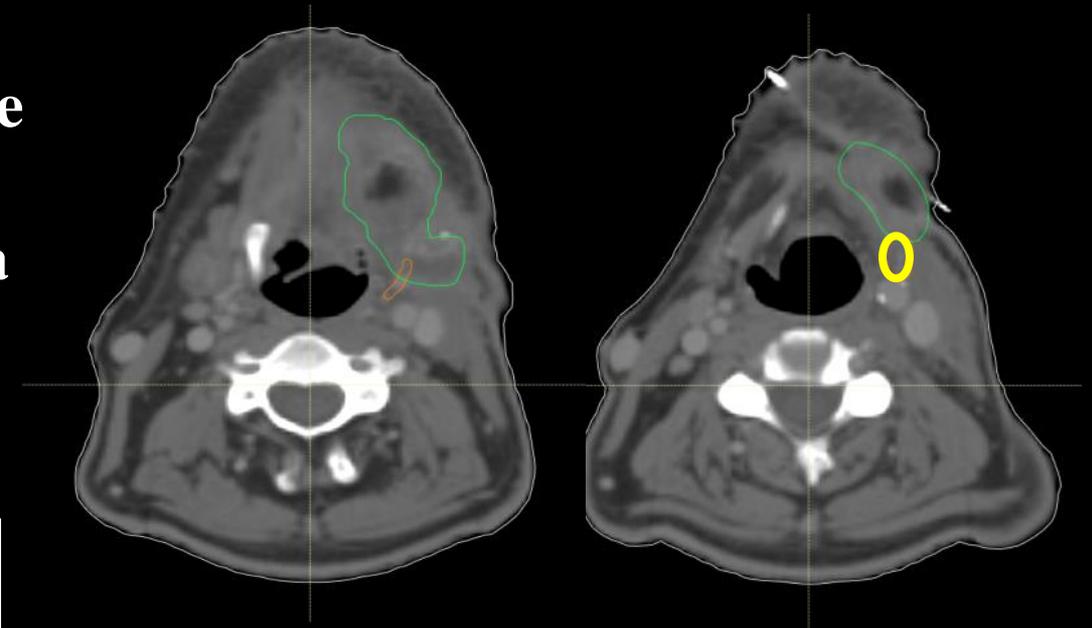


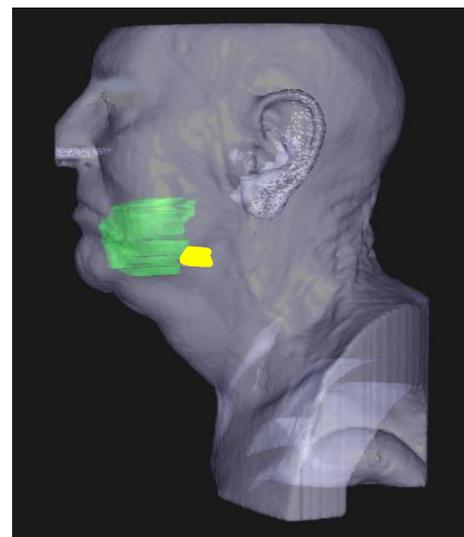
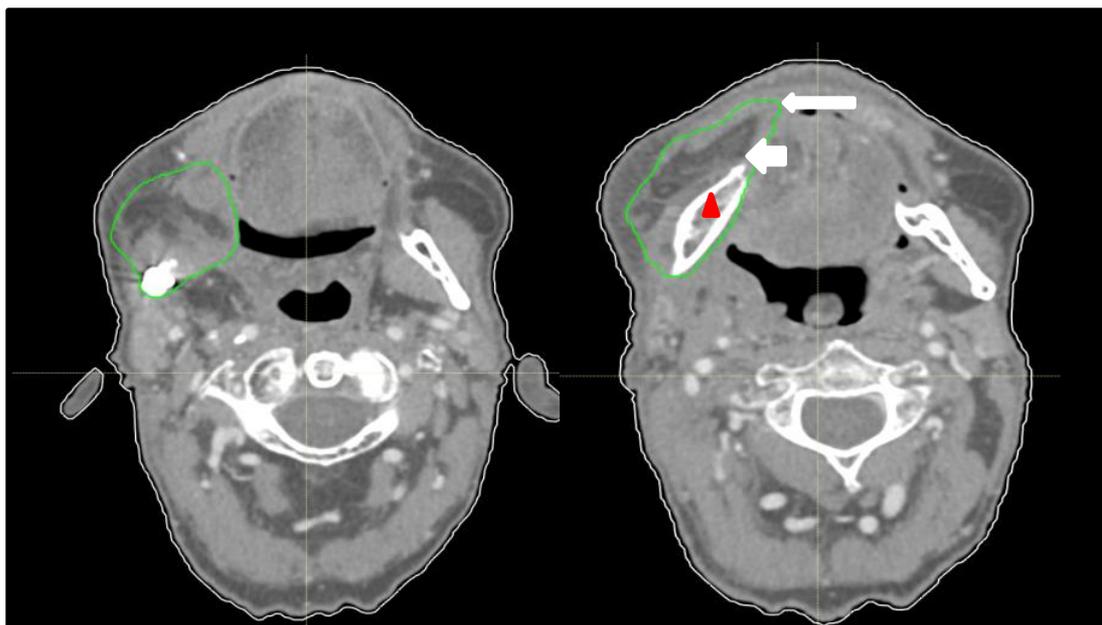
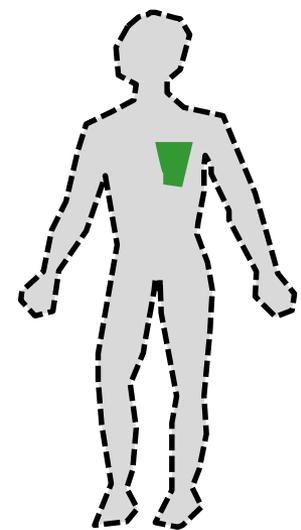


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-  **Bone**





-  **Body**
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-  **Fat**
-  **Bone**

