Original article

A simplified CT-based definition of the supraclavicular and infraclavicular nodal volumes in breast cancer

Règles de délimitation simplifiées des volumes ganglionnaires sus- et sous-claviculaires dans le traitement des cancers du sein

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A R T I C L E   I N F O

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A B S T R A C T

Purpose. — The available contouring guidelines for the supraclavicular and infraclavicular lymph nodes appeared to be inadequate for their delineation on non-enhanced computed tomography (CT) scans. For this purpose, we developed delineation guidelines for the clinical target volumes (CTV) of these lymph nodes on non-enhanced CT-slices performed in the treatment position of breast cancer.

Materials and methods. — A fresh female cadaver study as well as delineation and an anatomical descriptions review were performed to propose a simplified definition of the supra- and infraclavicular lymph nodes using readily identifiable anatomical structures. This definition was developed jointly by breast radiologists, breast surgeons, and radiation oncologists. To validate these guidelines, the primary investigator and seven radiation oncologists (observers) independently delineated 10 different nodal CTVs. The primary investigator contours were considered to be the gold standard contours. Contour accuracy and concordance were evaluated.

Results. — Written guidelines for the delineation of supra- and infraclavicular lymph nodes CTVs were developed. Consistent contours with minimal variability existed between the delineated volumes; the mean kappa index was 0.83. The mean common contoured and additional contoured volumes were 84.6% and 18.5%, respectively. The mean overlap volume ratio was 0.71.

Conclusions. — Simplified CT-based atlas for delineation of the supra- and infraclavicular lymph nodes for locoregional irradiation of the breast on non-enhanced CT-scan, have been developed in this study. This atlas provides a consistent set of guidelines for delineating these volumes.

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R É S U M É

Objectifs. — Les atlas de délimitation des aires ganglionnaires sus- et sous-claviculaire dans le cadre du cancer du sein sont, pour la majorité, basés sur des scanographies avec injection de produit de contraste. Ils sont de ce fait difficilement utilisables pour la majorité des centres qui pratiquent des scanographies de repérage sans injection. L’objectif de ce travail était de proposer des règles de délimitation reposant sur l’utilisation de repères anatomiques précis, identifiables en coupes axiales non injectées. 

Matériaux et méthodes. — Une revue de la littérature sur les outils d’aide à la délimitation des aires sus- et sous-claviculaire a été menée parallèlement à une étude du drainage lymphatique du sein sur cadavre. Après discussion entre radiologues, chirurgiens et oncologues radiothérapeutes, des repères anatomiques précis et facilement identifiables ont été retenus pour la définition des volumes. Afin d’évaluer la faisabilité et la reproductibilité de ces recommandations, sept oncologues radiothérapeutes ont indépendamment délimité dix aires ganglionnaires sus- et sous-claviculaires. La concordance des volumes a été évaluée à l’aide du logiciel Artiview P2E (Aquilab SAS).

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1. Introduction

Adjuvant radiotherapy is a standard component of breast cancer treatment. Two randomised trials have shown a significant survival benefit by the addition of postmastectomy radiotherapy in patients with positive axillary lymph nodes [1–3]. In these trials, patients were treated with comprehensive chest wall radiation that included the supraclavicular nodal bed. Although the contribution of supraclavicular nodal bed irradiation to the improvement in outcome was uncertain, it was clear from these studies that treatment to regional sites is of therapeutic benefit.

A typical supraclavicular nodal bed field includes the supra- and infraclavicular lymph nodes. This field is indicated for patients who have undergone an axillary lymph node dissection and are found to have regional lymph nodes with metastases. For such patients, this area is at the greatest risk for residual nodal disease, depending on the tumour characteristics and the nodal stage [4,5]. The supraclavicular nodal bed region is either treated with conventional radiotherapy using a single anterior field with a full dose prescribed to a point in the supraclavicular fossa (3 cm deep to the surface of the skin), or with 3-dimensional (3D) radiotherapy using treatment planning computed tomography (CT).

Importantly, previously published studies have shown that supraclavicular nodal bed region vary in depth. Conventional treatment with a standard prescription point for all patients was found to be inadequate [6,7].

In the literature, most of the delineation guidelines for this region are based on contrast-enhanced CT-scans that use vascular structures as boundaries for these volumes [7–12].

To the best of our knowledge, most centres in France use a non-enhanced CT-scan for the treatment planning of breast cancer patients; therefore, the application of these guidelines and the identification of these structures are quite difficult.

The purpose of this study was to develop an atlas for the delineation of the supraclavicular nodal bed region (the supra- and infraclavicular lymph nodes) on transverse non-enhanced CT-slices that are performed in the treatment position of breast cancer.

2. Materials and methods

2.1. Determining anatomical boundaries

The anatomical descriptions as well as the delineation guidelines [7–9] of the supra- and infraclavicular lymph nodes were studied to identify the anatomical boundaries of these regions.

In addition, a fresh female human cadaver study was performed to better understand the lymphatic drainage in patients with positive axillary lymph nodes. A careful bilateral dissection of the anterior chest wall and the neck was performed. The axillary lymph vessels were identified and injected with blue dye with a 30 G needle, and blue-stained afferent lymph collecting vessels were traced. The lymph vessels were found to pass underneath the pectoralis minor muscle towards the clavicle and then behind the clavicle towards the clavicular head.

Stained lymph nodes were found bilaterally behind the upper parts of the clavicular heads, as illustrated on Fig. 1.

These findings, as well as the previously mentioned descriptions and guidelines, served to aid the development of our delineation guidelines. Readily identifiable anatomical structures were selected and used to define the clinical target volumes (CTVs) of the supra- and infraclavicular nodal regions. This definition was developed jointly by breast radiologists, breast surgeons, and radiation oncologists.

2.2. Development of the delineation atlas

Non-enhanced CT-scans obtained in five patients, with different body habitus, who were consecutively treated with irradiation at our institution were used in this study. The patients lay in the supine position with both arms in abduction (90°) on a breast board. The CT-scan sections were contiguously obtained at 3-mm intervals from the neck to the diaphragm.

Using the proposed delineation instructions, the primary investigator delineated bilateral supra- and infraclavicular lymph node CTVs for all five of the patients. The contours were agreed upon by all of the investigators and considered to be the gold standard volumes for future reference.

2.3. Validation of the atlas

Seven radiation oncologists from our institution were recruited as observers for this study. Using the proposed guidelines, the observers separately contoured the same volumes as the primary investigator for the five previously mentioned patients.

Contour accuracy and concordance were evaluated by different indices. All of the indices were calculated using the volume analysis software Artiview™ (Aquilab®, Lille, France).

3. Results

3.1. Contouring atlas

Contouring instructions describing the anatomical boundaries of the supra- and infraclavicular lymph node CTVs and written guidelines for consistent delineation were developed (Table 1). The atlas was developed using only easily recognisable landmarks (skeletal landmarks, principle vessels and muscular structures) on non-enhanced CT-slices performed in the treatment position of breast cancer. Fig. 2 shows the corresponding structures illustrated in the CT-slices of one patient.

The supraclavicular lymph node CTV begins superiorly at the inferior border of the clavicular cartilage and extends inferiorly to the cranial border of the clavicular head (Fig. 2a–d). In the caudal CT-slices, the supraclavicular lymph node CTV remains dorsal to the sternocleidomastoid muscle and then extends laterally to the clavicle as the nodal regions approach the clavicle (Fig. 2b). For the cranial CT-slices, the volume extends to the lateral border of
the clavicle (Fig. 2c). The posteromedial border extends medially to the carotid artery and the internal jugular vein. The supraclavicular lymph node CTV is limited posteriorly by the scalenus anterior muscle.

The infraclavicular lymph node CTV begins at the superior border of the pectoralis minor muscle cranially and extends caudally to the superior border of the sternum (Fig. 2c–e). It extends laterally to the medial border of the pectoralis minor muscle and medially to the lateral edge of the clavicle. The infraclavicular lymph node CTV is limited by the pectoralis major muscle anteriorly and by the ribs and intercostal muscles posteriorly.

3.2. Validation study

The developed delineation guidelines were found to be rapidly and easily applicable to clinical practice by all observers in this study.

Utilisation of this atlas resulted in consistent contours with minimal variability between the contoured volumes. Using the volume analysis software, the Kappa index varied between 0.8 and 0.86 with a mean of 0.83. In the comparative analysis of observer contoured and GS volumes, the mean common contoured volume was 84.6% (range: 81–87%). The mean additional contoured volume was

<table>
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<th>Table 1</th>
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<tr>
<td>Guidelines for delineating the anatomical boundaries of supra- and infraclavicular lymph node clinical target volumes, for breast cancer patients in treatment position, on non-enhanced transverse computed tomography (CT) slices.</td>
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<tr>
<td><strong>Cranial</strong></td>
</tr>
<tr>
<td><strong>Supraclavicular lymph nodes</strong></td>
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<tr>
<td><strong>Infraclavicular lymph nodes</strong></td>
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* For CT-slices, where nodal regions approach the clavicle.
18.5% (range: 12–26%). The mean overlap volume ratio was 0.71 (range: 0.67–0.74). Detailed results are presented in Table 2.

4. Discussion

Using information obtained from anatomical descriptions, delineation guidelines and the cadaver study, we have identified easily recognisable anatomical boundaries on non-enhanced CT-slices for the delineation of supra- and infraclavicular lymph nodes CTVs. As shown by previously published studies, arm position can affect the location of these lymph nodes [8,9,11]. Therefore, these guidelines are specifically proposed for patients lying in the supine position with both arms in abduction (90°) on a breast board.

According to our guidelines, the superior boundary of the supraclavicular CTV is slightly more caudal compared to the boundary described by Madu et al. and Kirova et al. (thyroid cartilage) [7,9], but corresponds to that described by Dijkema et al. and the Radiation Therapy Oncology Group (RTOG) guidelines [8,10]. The inferior boundary corresponds to the guidelines of the RTOG and is much easier to identify than those described by Madu et al., Kirova et al. and Dijkema et al. (subclavian artery). Unlike the description by Dijkema et al., the supraclavicular is not divided into two volumes (medial and lateral) and does not extend to the trapezius muscle. However, it extends to the lateral edge of the clavicle in the caudal CT-slices. This lateral part may have a high-risk for recurrence, as suggested by a study reporting on the distribution of lymph nodes...
52 supraclavicular nodal bed recurrences according to PET/CT. This study of 32 patients with advanced breast cancer disease found 11 (21\%) of these lymph node recurrences in the posterior triangle region [13]. Despite all of the limitations of this study, this finding might indicate the need for reasonably adequate lateral coverage of supraclavicular lymph node region.

The boundaries of the infraclavicular CTV correspond to those described by Madu et al. and Kirova et al. except the posterior boundary which extends more dorsally to the ribs and the intercostal muscles. The same descriptions were provided by Dijkema et al.

The application of the atlas resulted in consistent and accurate contours as measured by different indices. The Kappa index of all of the structures was greater than 0.8, indicating excellent concordance. Small discrepancies between the contoured volumes were mainly noticed in the lateral limit of the supraclavicular lymph nodes and the superior limit of the infraclavicular lymph nodes; however, this interobserver variability was relatively minor and acceptable.

The major limitation of this study is that this atlas was only validated by investigators from our institution.

5. Conclusions

We have developed a simple atlas that proves to consistently provide accurate contours. This study serves as the first step towards consistent guidelines for the delineation of supra- and infraclavicular lymph nodes on non-enhanced CT-slices. This atlas is under evaluation by five radiation oncology centres specialising in breast cancer treatment in France, with the aim of developing a national contouring consensus.

Disclosure of interest

The authors declare that they have no conflict of interest concerning this article.

References


