Head and Neck Nodal Station Images: Guidance for Three-dimensional Radiation Therapy Treatment Planning

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When we use radiation to treat cancer patients, the irradiated volume usually encloses the detectable tumor and any metastatic areas that are thought to be at risk. Usually, in three-dimensional (3D) radiation therapy, we need to define the clinical target volume (CTV), which identifies the areas suspected of containing microscopic metastasis. We can use a set of computed tomographic (CT) images to define these suspected areas, which we relate to nodal station distributions. The traditional method uses special anatomic landmarks for such definition. This lymph node image guidance method uses a set of CT images to show the relevant nodal stations and find the correlation between the suspected areas and the lymphatic pathways. First, we used CT images from head and neck cancer patients. Then, we designed a program to delineate the regional lymphatic areas in order to distinguish the position of all the major lymph nodes in the head and neck region. These lymph nodes were then used to assist the oncologist in developing treatment references. Finally, we established a database management system to determine the relationships between different lesions and lymph nodes, as well as correlations, with metastatic pathways. Defining these relationships on the CT images provided oncologists specific information that could be used to define the CTV more precisely for 3D radiation therapy.

KEY WORDS: Treatment planning, lymphatic system, computed tomography

ACCURATE PATIENT ANATOMIC POSITION and the delivery of treatment dose are key elements for successful radiation therapy of cancer patients. This is especially important for the use of three-dimensional radiation therapy (3DRT). The goal of 3DRT in cancer patients is to irradiate a chosen field to the desired dose, and to increase tumor control probability while sparing as much as possible of the adjacent normal tissue. Computed tomography (CT) has been the major imaging technique for staging and radiation treatment of

head and neck cancers.¹⁻⁵ Its value lies in the superior quality of imaging obtained with CT. Furthermore, it is faster and can be less costly than other modalities, such as magnetic resonance imaging (MRI).⁶

Using CT images to provide the target volume for radiation therapy increases the importance of accurate anatomic delineation. The lymphatic pathways are the main routes along which the cancer cells metastasize. For most tumors, radiation therapy will encompass the nodal stations that are near the primary lesion. This is especially important for increasing the local tumor control rate and preventing spread through lymphatic pathways.⁷⁻¹¹ Traditionally, the radiation oncologist establishes the location and boundaries of different nodal stations on standard two-dimensional simulation radiographs. With 3DRT, the radiation oncologist has to face the new challenge of defining the virtual clinical target volume (CTV) on a set of cross-sectional (2D) CT images.

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Table 1. Abbreviations in Tables and Figures

Abbreviation	Noal Group
ATL	Anterior tongue lymphatics
IJN	Internal jugular nodes
PAuN	Preauricular nodes
PG&N	Parotid gland and nodes
PsRN	Superior posterior pharyngeal wall lymphatics and retropharyngeal nodes
SAN	Spinal accessory nodes
SMaN	Submandibular nodes
SPL	Soft palate lymphatics
TL	Tonsil lymphatic plexus
u	Upper subgroup
m	Middle subgroup

Head and neck lymph node classifications have been described by several authors.¹²⁻¹⁴ Such classifications assist the radiation oncologist in defining the lymph nodes location for treatment. To improve the accuracy and productivity of the radiation oncologist in delineating the lymphatic areas to be treated, the cross-sectional nodal atlas has to be integrated with both the imaging system employed and the treatment planning system. In this study, CT images from head and neck cancer patients were imported into a personal computer through scanning of hardcopy. After the CT image data sets were scanned, we used Borland C++ Builder 5 (BCB5) programing software (Inprise Corporation, Scotts Valley, CA) to delineate the lymph node contours according to anatomic site and lymphatic classification. Finally, we

used the BCB5 Database Desktop system to manage the cross-sectional CT images according to their node classifications and to display the lymph node stations and the relationship of their lymphatic pathways based on the clinical situation.

The methods we developed are intended to assist the radiation oncologist in defining the lymph nodes more precisely on the CT images of patients to be treated and also in developing the follow-up treatment plan.

MATERIALS AND METHODS

Image Acquisition

CT images were acquired in patients with a suspected head and neck tumor. We used a Uni-Frame (Med-Tec, Orange City, IA) patient positioning and immobilization system during CT scanning. The patient was placed in the supine position, lying on a flap-top couch and wearing a mold mask attached to a head support. The CT scans were obtained using a HeliCAT II scanner (Elscent Ltd., Tel Aviv, Israel) with 120 kV tube voltage, 100 mA tube current, and 2-second scan time. Slice thickness and spacing was 5 mm for the radiotherapy treatment planning (RTP) image sets. The image had an in-plane matrix size of 340 × 340 pixels, and the scan diameter of each image was 250 mm. Fifty images were typically generated for the whole head and neck region. A coronal view topogram was simultaneously taken to comparison of the CT images and the corresponding anatomic positions.

After image acquisition, the CT data sets were exported using a DICOM Gateway (Elscent Ltd., Tel Aviv, Israel) to our RTP system, Render Plan 3-D (Precision Therapy In-

Table 2. Selected Lymph Nodes of Head and Neck

Anatomic Site	First Echelon Nodal Group	Abbreviation
Nasal cavity	Retropharyngeal nodes	PsRN
	Internal jugular nodes	IJNu
Paranasal sinuses	Retropharyngeal nodes	PsRN
	Internal jugular nodes	IJNu
Tonsil	Internal jugular nodes	IJNu
	Internal jugular nodes	IJNu
Nasopharynx	Retropharyngeal nodes	PsRN
	Internal jugular nodes	IJNu
	Spinal accessory nodes	SAN
Pyriform fossa	Internal jugular nodes	IJNu, m
Posterior pharyngeal wall, superior	Retropharyngeal nodes	PsRN
	Internal jugular nodes	IJNu
Posterior pharyngeal wall, inferior	Internal jugular nodes	IJNm
Supraglottic larynx	Internal jugular nodes	IJNu, m
Parotid gland	Parotid nodes	PG&N
	Submandibular nodes	SMaN
	Submandibular nodes	SMaN
Submandibular gland	Internal jugular nodes	IJNu

Fig 1. Cross-sectional CT image of head and neck region at level HN-07 (see Fig 2).

ternational, North Miami Beach, FL) for reformatting. The reformatted CT images were transmitted using file transfer protocol (ftp) to a Codonics NP-1600M medical color printer (Codonics Inc., Middleburg Heights, OH) on the local area network (LAN).¹⁵ This printer provided hard-copy output that was then scanned into an the IBM personal computer (PC) and stored on the hard disk as bmp (bit map) files. With our present hardware, this was the simplest and fastest way to get the CT data into the PC. The computer used was an IBM personal computer 300GL with 500 MHz Pentium III central processing unit and 128 MB RAM (IBM Corporation, White Plains, NY) with the Windows98 operating system (Microsoft Corporation, Redmond, WA). The graphical interface used the BCB5 programing language to perform the Windows graphics display, which included user interaction dialog boxes. Using dialog boxes in the software developed, the final graphical display of lymph node CT images could be transmitted using ftp to the Codonics NP-1600M medical color printer for high-quality hardcopy output for documentation.

Lymph Node Contouring

The process described in this article uses CT original images on which the lymph nodes have been outlined. To establish nodal station reference images, we used CT images of known head and neck cancer patients and delineated lymph nodes on those CT images. When a study patient's CT images are obtained, the contour of each lymph node is outlined according to its anatomical position, and these

Fig 2. A sagittal view topogram CT image showing levels of HN-01 to HN-16.

positions are in accordance with those present in the nodal station tables. With the BCB5 programing software, we have designed a program to delineate the lymph nodes on study patient CT images and store the contours of the nodes in the form of a set of coordinate locations (instead of bmp image files). Subsequently, when the contours are read, the coordinates are used to locate the contour positions in the CT image, and then they are shown on the screen, together with the relevant images.

Nodal Stations Database

Because of the complexity and variety of lymph nodes included in the nodal station atlas, the lymph node data management is based on several data banks built under Database Desktop in the BCB5 system. The goal is to make future program design more convenient and faster for the task of lymph node classification and localization. In the preset nodal station tables, the lymph nodes in the head and neck region are divided into corresponding areas according to anatomic locations from Rouviere's and other lymphatic anatomic references.¹²⁻¹⁴ Major lymph node groups in each area are listed in tables, and the abbreviation for each lymph node is included in the tables for the convenience of comparison with its image. The tables contain the first echelon nodal stations as well as the node abbreviations.

Fig 3. An example of saved CT images with the lymph node contours in place.

RESULTS

Abbreviations of the node groups reported in this article are given in Table 1. The head and neck lymphatic system for anatomic site and the lymphatic drainage to the first echelon nodal stations (with node abbreviations) are listed in Table 2. A set of consecutive and equidistant head and neck cancer patient CT scan images were taken as original CT data and scanned into the PC. Figure 1 represents one of the scanned CT images of the head and neck region at level HN-07 with an image matrix of 340 × 340 pixels. A coronal view topogram CT image with the levels of HN-01 to HN-16 of the same patient for connecting the CT images with the bone structure is shown in Figure 2. After these CT image data sets were scanned into the PC, the lymph nodes were contoured according to their anatomic site and lymphatic classification.

The BCB5 programming language delineated, organized, and saved the results to the hard disk as demonstrated in Figure 3. Finally, several data banks were built with the help of Database Desktop under the BCB5 system, and they are managed according to anatomic location as well as lymphatic classification. An executed result for selected lymph nodes PG&N (parotid gland and nodes) and superior posterior pharyngeal wall lymphatics and retropharyngeal nodes [PsRN] in the level HN-07 CT image is shown in Figure 4. Meanwhile, we can quickly find all the connecting CT images on the screen easily when we choose desired lymph node groups from those stored in the PC. A program run showing the result for selected retropharyngeal nodes (PsRN) is illustrated in Figure 5. By means of database management, it can make future program design more convenient and the query speed faster.

Fig 4. A program result for selected lymph nodes, PG&N and PsRN (see Table 1), in the level HN-07 CT image.

DISCUSSION

Computed tomography is the principal tool used to evaluate primary tumors and any metastases to the body, and it has become an invaluable aid in staging tumors and guiding radiation oncologists in treatment planning. Computed tomography is also the most commonly used imaging modality in cancer patients. With the development of 3D conformal radiation therapy (CRT) and the introduction of CT planning systems, it has become feasible to deliver an adequate radiation dose to the target while sparing the healthy surrounding tissue. Unfortunately, many of the lymph node groups are not easily distinguished on CT and, therefore, are not particularly suitable for CT-based target definition. An adequate target definition for the primary cancer as well as for the regional lymph nodes and surrounding healthy tissues on CT is essential.

In this article, we have described the use of CT as an original imaging method from which data were gathered to define the lymph node regions in the head and neck area. The CT images were acquired with the patient in the same position as for treatment. A coronal view topogram was taken as a reference to aid in connecting the CT images with the corresponding anatomic sites. After image acquisition, the CT data sets were processed according to the procedure described in the *Methods* section. The resultant lymph node contours, by using the BCB5 algorithm we developed, are stored in the PC as a set of coordinate locations. In this way, the integrity of the original CT images is maintained, management of lymph node station files is convenient, and less disc space is needed than for storing the images plus an overlay showing node contours. When the nodal station is connected with the image contours, reference images can be displayed easily

Fig 5. An illustration of the program result for selected retropharyngeal nodes (PsRN).

to assist the radiation oncologist in defining the lymph nodes accurately.

In a set of CT data, every cross-sectional CT image contains several different lymph nodes. We have used the BCB5 Database Desktop system to manage these node locations according to the classification scheme shown in Table 2. When a specific node is chosen, desired lymph node locations and their pathways can be selected using an on-screen dialog box. The program then automatically shows all the related CT slices and lymph node contours on screen. This assists the physician by providing a view of lymphatic areas and pathways on each slice.

We believe the nodal station images and pathways generated by the program can help the radiation oncologist define the different nodal stations on cross-sectional CT images more accurately and thus guide the choice of CTV more effectively than use of conventional

anatomic landmarks. Our study so far shows that lymph node CT image contouring and desktop database management for reference nodal stations and pathways were found to be useful to the radiation oncologist in radiation treatment planning. This image-based guidance system can provide the precision and reproducibility of nodal localization and furnish the physician with clinically useful guidelines.

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