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Educational review

Anatomical bases for the radiological delineation of lymph node areas. Upper limbs, chest and abdomen

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Abstract

Cancer spreads locally through direct infiltration into soft tissues, or at distance by invading vascular structures, then migrating through the lymphatic or blood flow. Although cancer cells carried in the blood can end in virtually any corner of the body, lymphatic migration is usually stepwise, through successive nodal stops, which can temporarily delay further progression. In radiotherapy, irradiation of lymphatic paths relevant to the localisation of the primary has been common practice for decades. Similarly, excision of cancer is often completed by lymphatic dissection.

Both in radiotherapy and in surgery, advanced knowledge of the lymphatic pathways relevant to any tumour location is an important information for treatment preparation and execution. This second part describes the lymphatics of the upper limb, of the thorax and of the upper abdomen. Providing anatomical bases for the radiological delineation of lymph nodes areas in the axilla, in the chest and in the abdomen, it also offers a simplified classification for labeling the mediastinal and intra-abdominal nodal levels, grouped in each location inside three major functional areas (called I, II and III) which are all divided into three sublevels (named a, b or c).

Keywords: Radiotherapy; Thoracic cancer; Abdominal cancer; Lymphatics; CTV

The first part of this series described the major lymphatic collecting trunks and the lymphatic drainage of the head and neck region (to be published in Radiotherapy and Oncology [9]). The second part, ''Anatomical bases for the radiological delineation of lymph node areas'', deals with the lymphatic of the upper limbs, thorax and abdomen. It is an anatomical description of major and minor lymphatics, more detailed than previously published material [18]. As in the head and neck region, there is still some inconsistency in the way various observers actually delineate lymph node stations relevant to the radiotherapy of various chest tumours [16]. It points to the need of an unambiguous anatomical description of the localisation of lymphatics.

The topography of the lymphatic system in the upper limbs is presented for the first time, of interest for the treatment of melanoma and other skin cancers, as well as some particular types of soft tissue sarcoma with a lymphatic spread (angiosarcoma, synoviosarcoma, etc.).

Also of interest are the anatomical landmarks used to delineate levels I, II and III in the axilla. It should be acknowledged that this distinction is not anatomical, since it does not reflect distinct afferent pathways as it does in the head and neck region (and elsewhere). Rather, it is a guide for a systematic approach to nodal dissection in the course of breast cancer surgery. Two relevant stations are added, the interpectoral (iP) and the parasternal (pS) stations (see Fig. 1).

Further, the thoracic lymphatics are presented according to a classification in functional areas, following the logics of afferent pathways, rather than using the less clear classification in levels of the American Thoracic Society [10].

A distal extension of the ATS classification has also been proposed by Korst et al. [6], to account for the frequent invasion of upper abdominal nodes by oesophageal tumours. It adds levels 15—20, to the levels 1—14 of the former. However, this nomenclature is not consistent with the one commonly proposed for gastric cancer surgery by the Japanese Research Society for the Study of Gastric Cancer [4]. This creates confusion and inconsistency in the reporting of nodal dissection of tumours located at the cardia.

The present way of labeling the chest and abdominal lymph node stations is thus relevant to both thoracic cancer (lung cancer, oesophageal cancer, and to a lesser extent lymphomas) and upper abdominal cancer (gastric cancer, bile duct cancer, etc.). It offers also clear vascular and vertebral landmarks for delineation of surgical and conformal radiotherapy target areas, which is not the case in the ATS or JRSGC maps, unless the more recent classification of Korst is used [6].

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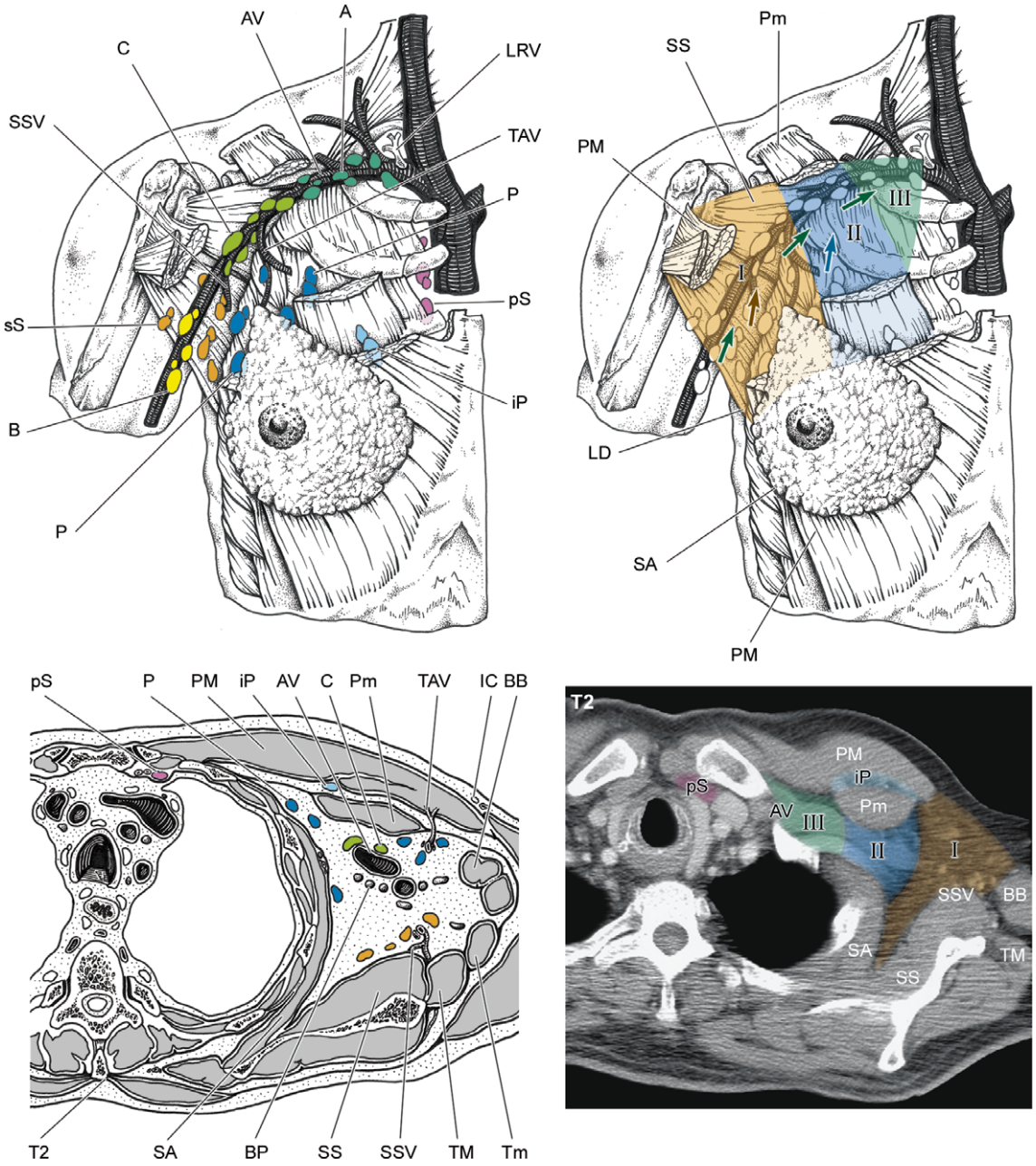

Fig. 1. Anatomical, surgical and radiological delineation of axillary lymph node areas. Anterior view of the axilla and chest after partial removal of the pectoral muscles with the corresponding levels (I—III) indicated on anatomical and CT sections. Lymph nodes are identified as follows: *the brachial (B), pectoral (P), interpectoral (iP), subscapular (sS), central (C), apical (A) and the parasternal (pS) groups*. The anatomical key structures to delineate the target volumes are: *the pectoralis major (PM), pectoralis minor (Pm), serratus anterior (SA), latissimus dorsi (LD), teres minor (Tm), teres major (TM) and the subscapular (SS) and biceps brachii (BB) muscles. Other landmarks are given by the axillary vessels (AV), surrounded by the nerves of the brachial plexus (BP), and by the subscapular (SSV) and thoraco-acromial (TAV) arteries and veins*. Levels (I—III) are bounded by the successive borders of the PM and Pm muscles, respectively, and do not match the limits of the anatomical node groups.

Lymphatics of the upper limbs

All the lymphatics of the upper limbs drain into the large nodes of the axilla, either directly or after passing through an intermediate group of small nodes. They are arranged in two layers, and either run superficially in the subcutaneous tissue converging towards the superficial veins, or course under the deep fasciae as close satellites of the main neuro-vascular bundles [15].

Axillary lymph nodes

The axillary nodes collect the lymph not only from the entire upper limb, but also from the cutaneous tissue of the upper part of the trunk and from the subjacent muscles (Fig. 1). Very large in size, they vary in number from 12 to 30 and are scattered in the cellulo-adipose tissue within the axilla. According to their afferent vessels and respective relationships with the vascular structures of the axilla, they

are divided into five groups which, however, are not clearly delineated [12,14]:

The *lateral* or *brachial group* includes four to six nodes situated on the infero-medial side of the axillary vein. Their afferent vessels drain the lymph from the superficial and deep compartments of upper limb, except for the superficial vessels of the arm that run alongside the cephalic vein. Their efferents have a threefold termination: most of them terminate in the central or apical groups, while others pass into the supraclavicular nodes [12].

The *anterior* or *pectoral group* is composed of four to five nodes located behind the pectoralis major muscle and along the lower border of the pectoralis minor. Forming a chain along and behind the lateral thoracic vessels, these nodes receive afferent vessels from the skin and muscles of the anterior and lateral walls of the trunk above the umbilicus. They also drain the lateral parts of the breast, and their efferent vessels extend to the central and apical groups of axillary nodes [19].

The *posterior* or *subscapular group* comprises six to seven nodes arranged above one another in a chain that follows the subscapular vessels, in the groove which separates, on the posterior wall of the axilla, the teres major and subscapularis muscles. The afferent vessels of this group collect the lymph arising from the muscles and skin of the back and from the scapular area downwards to the iliac crest. Their efferent vessels drain into the central and apical lymph nodes [14].

The *central group* of axillary nodes usually contains three to five extremely large nodes, located in the central part of the adipose tissue of the axilla between the preceding chains which progressively converge towards them. Their efferent vessels then extend to the apical group [20].

The *apical group* contains six to 12 large lenticular nodes which occupy the apex of the axilla, behind the upper portion of the pectoralis minor and partly above this muscle. The majority of these nodes rest on the infero-medial side of the proximal part of the axillary vein, in close contact with the upper digitations of the serratus anterior. Receiving afferent vessels from all the other axillary nodes, they also drain some superficial vessels running along the cephalic vein. The efferent vessels of this group unite to form the subclavian trunk which finally opens into the right lymphatic duct on the right side, or into the thoracic duct on the left side [19].

Superficial lymph nodes

Located on the surface of the deep fasciae, the superficial lymph nodes of the upper limbs are few in number and are invariably located in the subcutaneous tissue [12,15]. Interposed on the superficial lymphatic pathways, they are known as the *supratrochlear* and *infraclavicular* groups (Fig. 2).

The *supratrochlear node* is usually isolated and deeply embedded in the subcutaneous fat, just over the deep fascia about 4–5 cm above the medial epicondyle of the humerus. Draining the superficial lymphatic pathways ascending from the ulnar side of the forearm, it sends effer-

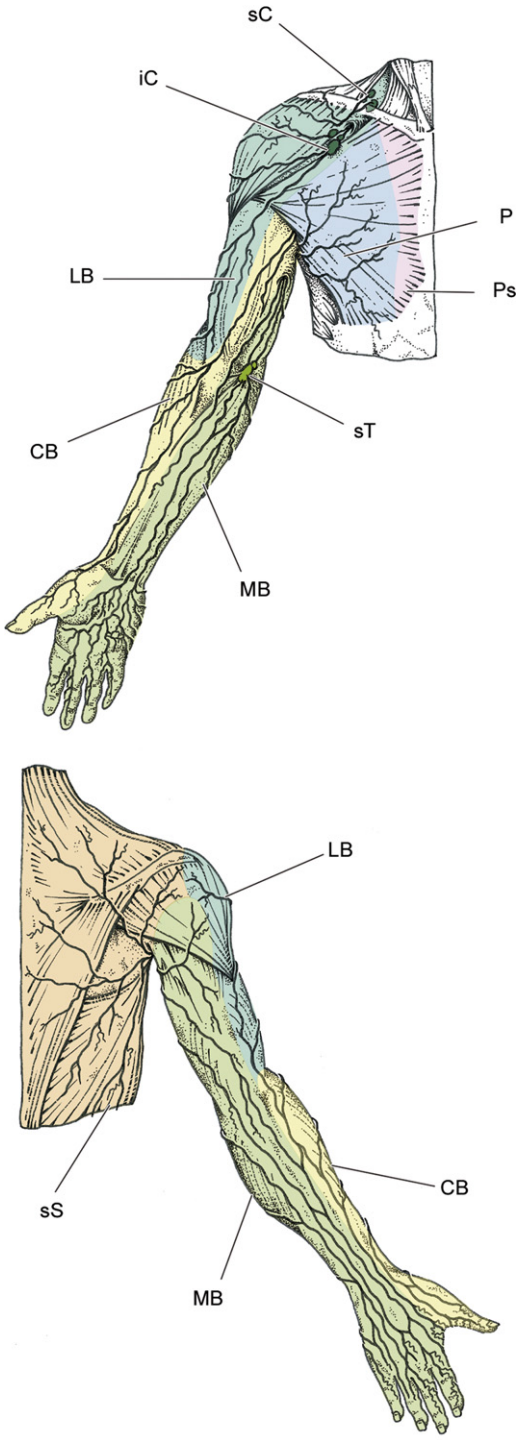

Fig. 2. Superficial lymphatic pathways of the upper limbs. Anterior and posterior anatomical views showing the distribution of vessels and nodes of the upper limbs. Nodes are identified as follows: *the supratrochlear (sT), infraclavicular (iC) and supraclavicular (sC) nodes. Collecting vessels form three ascending drainage pathways classified as the medial brachial (B), central brachial (cB) and lateral brachial (LB) pathways*. Parietal vessels of the anterior and posterior chest walls run into the pectoral (P), parasternal (pS) and subscapular (sS) groups of nodes, respectively.

ent vessels, which accompany the basilic vein to join the deep subfascial vessels.

The *infraclavicular nodes* are one to two in number, and consist of small interrupting nodes located near the cephalic vein in the deltopectoral groove. They are traversed by the superficial lymphatic vessels, which drain the lateral skin of the arm and shoulder. Their efferent vessels pierce the clavipectoral fascia immediately below the clavicle and terminate in the apical group of axillary nodes. Nevertheless, some other vessels cross the anterior border of the clavicle and finally reach the deep cervical nodes of the supraclavicular group [19].

Functional drainage pathways

On a functional level, the superficial and deep lymphatic pathways of the upper limbs are almost completely segregated by the deep fasciae. Nevertheless, they finally converge towards the axilla and communicate with each other at both locations where the superficial vessels, running alongside the basilic and cephalic veins, accompany them through Morestin's and Cruveilhier's fascial foramina and then join the deep perivascular lymphatic channels [12].

The *superficial lymphatic pathways* (Fig. 2) issue from all parts of the cutaneous layers of the upper limb and originate in the hand from an extremely dense network with maximal development on the palmar surface of the fingers. These digital plexuses are drained by small collecting vessels which first follow the corresponding collateral artery but then incline backwards and pass into the dorsal aspect of the hand. The remainder of the palm is drained by vessels which course in front of the wrist and divide into medial, lateral and central small trunklets which then ascend towards the forearm along its ulnar, radial and palmar aspects [14]. On the posterior surface of the forearm, the dorsal antebrachial channels pass progressively around the medial and lateral borders of the limb to join the vessels that course in front of the elbow. As they run upwards, these channels gradually decrease in number, and finally separate into three distinct superficial brachial pathways [8]:

The *medial brachial collecting vessels* follow the basilic vein, and some of them pass through the supratrochlear nodes above the elbow. Thereafter they perforate the fascia with the vein, join the deep collectors, and end in the brachial group of axillary nodes.

The *central brachial collecting vessels* run longitudinally over the fascial sheath of the biceps brachii, pierce the axillary fascia along the anterior axillary fold, and terminate in the brachial nodes.

The *lateral brachial collecting vessels* are associated with the cephalic vein and continue their course on the lateral side of the biceps brachii until they reach the deltopectoral groove. At this point most of them empty into the brachial group of axillary nodes. A few transit by the infraclavicular nodes which also receive lateral afferents from the deltoid area. Efferents from these nodes end as previously stated in the apical axillary nodes and sometimes in the cervical supraclavicular node [17], adjacent to region IV of the head and neck region [3].

During their course, the longitudinal superficial vessels undergo many divisions which sometimes diverge and sometimes converge, thereby creating several connections between the dorsal, central, lateral and medial pathways organised around the arm and forearm. Because of the large number of randomly distributed anastomosing channels, the pattern of lymphatic spread of a cutaneous tumour such as a melanoma is difficult to predict: for instance, the dissemination of a dorsomedial melanoma of the hand can first involve the palmar supratrochlear node, then the brachial group of the axilla [8]. The potential however exists that if the dorsal collecting trunklets incline more likely around the lateral border of the forearm, there is a possibility of primary metastatic nodes being present in the infraclavicular group and then immediately in the apex of the axilla.

The *deep lymphatic pathways* of the upper limb comprise large collectors which are few in number and relatively less anastomosing than the superficial channels. Running around the axial vessels, they form radial, ulnar, interosseous and brachial ascending pathways which drain into the lateral brachial nodes of the axilla. Along their course small nodes can be found. Within the axilla, the main lymphatic channels arising from the lateral, anterior and posterior nodes successively pass through the central and apical groups of nodes. During their course along the axillary vein, they sequentially cross three topographical segments [1,7] located, respectively, behind the lower part of the pectoralis major (level I), behind the pectoralis minor (level II), and finally above the upper border of the pectoralis minor in the subclavicular triangle (level III), adjacent to level IV of the head and neck region.

Closely linked to the lymphatic pathways of the upper limb, the *lymphatic vessels of the breast* are mainly directed toward the axilla (Fig. 1). Originating from a dense plexus in the interlobular connective tissue of the breast they communicate with the overlying subcutaneous network, especially around the nipple, giving rise to a subareolar circular plexus [15]. The latter is drained by two or three main collectors which turn around the inferior border of the pectoralis major and which become satellites of the lateral thoracic vessels [2,7,17]. Behind the muscle the *principal lymphatic pathway of the breast* thus reaches the anterior pectoral group of axillary nodes. Nevertheless, three *alternative drainage pathways* also exist, explaining the other primary locations of metastatic lymph nodes observed in breast cancer.

The first accessory route is constituted by direct lymphatic vessels of the inferolateral part of the breast which adopt a more dorsal route and join the posterior subscapular nodes of the axilla [7].

The second route involves lymphatic channels which arise from the upper parts of the gland and tend to follow the cutaneous branches of the thoraco-acromial artery. Most of these vessels pass through the fascicles of the pectoralis major and drain immediately into the apical axillary nodes. Between the pectoralis major and minor muscles, some of these vessels are interrupted by a large inconstant interpectoral node, usually known as Rotter's node [5,7]. Others encounter the infraclavicular and supraclavicular nodes.

The third alternative pathway is directed medially and comprises several channels running alongside the cutaneous

perforating branches of the internal thoracic artery. Like the latter, these vessels perforate the medial attachments of the pectoralis major and the intercostal muscles and terminate in the parasternal lymph nodes [1,5].

Delineation of lymph node areas

Except for the infraclavicular nodes which are located in the subcutaneous tissue facing the deltopectoral groove, all the main lymphatic groups of the upper limb are scattered within the quadrangular pyramidal space of the axilla. Filled with adipose tissue, the latter is easily delineated on CT and MR images as follows (Fig. 1): its anterior wall is constituted by the deep surfaces of the pectoralis major and minor muscles. Posteriorly, it is bounded by the subscapularis, teres major and latissimus dorsi muscles while the serratus anterior, covering the chest, delineates its medial boundary. Its lateral surface is usually narrowed and corresponds to the muscles of the arm running along the anteromedial surface of the humerus. The almost virtual base of the axillary volume corresponds to the tissue between the inferior borders of the pectoralis major anteriorly and the latissimus dorsi posteriorly [8]. Directed upwards and medially, the apex of this volume is confined between the clavicle and the first rib and communicates in the manner of the constricted part of a sandglass, with the enlarged base of the supraclavicular area.

Within this volume, the inferior border of the pectoralis major and the inferolateral and superomedial edges of the pectoralis minor can be used as anatomical landmarks to separate the inferior (I), middle (II) and superior (III) levels of the axillary space. Narrowing progressively, these levels contain the anterior (pectoral), lateral (brachial), posterior (subscapular) and central groups of nodes (level I), then the central and apical groups of nodes (levels II and III), contiguous with their satellite axillary vessels and nerves from the brachial plexus.

Lymphatics of the thorax

The lymphatic system of the chest is clearly divided into two different functional groups of vessels and nodes. The first comprises the parietal lymphatics which drain the diaphragmatic and sternocostal walls of the thorax. The second concerns the visceral lymphatic system, associated with the various organs within the thoracic cavity [20].

Parietal vessels and nodes

Linked to the anterior, lateral and posterior integuments of the chest, the *superficial lymphatic vessels* of the thoracic walls ramify subcutaneously and converge towards the subscapular or pectoral axillary lymph nodes (Fig. 2). Those running along the anterior surface of the sternum may cross the midline and usually drain into the parasternal nodes, as previously described for the medial breast collectors [12,14].

The lymph vessels of the *deep parietal system* drain the muscles of the chest wall and, depending on their origin, join three groups of nodes, i.e. the parasternal, intercostal and superior diaphragmatic nodes (Fig. 3).

There are four to five *parasternal* or *internal thoracic nodes* on each side. Located behind the anterior ends of the intercostal spaces alongside the internal thoracic vessels, these nodes are separated from the anterior aspect of the pleura by the transversus thoracis muscle and the endothoracic fascia. Collecting vessels from the breast, they also receive afferents from the deepest parts of the anterior thoracic and abdominal walls above the umbilicus [15]. Through a small group of nodes concealed behind the xiphoid process, they also drain the lymph from the superior part of the diaphragmatic surface of the liver. Their efferent vessels usually unite with those of the visceral nodes to form a single channel, the bronchomediastinal trunk, which terminates in the right or left large collectors, but which may also open directly into the internal jugular or subclavian veins [19].

The *intercostal nodes* are located dorsally and occupy the posterior extremities of the intercostal spaces in front of the head and neck of the ribs. They receive afferent vessels that are satellites of the posterior intercostal arteries. Their efferents drain into the thoracic duct on the left, or into the right lymphatic duct on the right side.

Scattered over the upper surface of the diaphragm, the superior *diaphragmatic nodes* are distributed into three separate groups on the anterior, lateral and posterior fleshy fascicles of the muscle. The anterior nodes are connected by their afferents to the liver and drain into the parasternal nodes. Arranged around the point where the phrenic nerve enters the diaphragm, the lateral diaphragmatic nodes are located close to the pericardium, and on the lateral aspect of the inferior vena cava on the right side; they collect the lymph from the costal part of the diaphragm and their efferents empty into the brachiocephalic or the posterior mediastinal nodes [13,15]. Finally, the posterior diaphragmatic group (*level 15* in [6]) consists of a few nodes on the back of the diaphragm, associated on the one hand with the abdominal aortic nodes, and on the other with the posterior mediastinal nodes [17,19].

Visceral vessels and nodes

The lymphatic nodes which drain the vessels originating from the thoracic viscera are all spread in the anterior, middle and posterior compartments of the mediastinum (Fig. 3). Depending on their location, they are classified as brachiocephalic, tracheobronchial and posterior mediastinal nodes [20]. They are thereafter detailed, together with their correspondence to the thoracic levels of the joined AJCC and UICC node classification, in italic [10].

The *brachiocephalic nodes* occupy the anterior part of the mediastinum around the brachiocephalic vein (*level 1: highest mediastinal nodes*), in front of the aortic arch (*level 6: pre-aortic nodes*), or between the large arterial vessels arising from the heart (*level 5: aortopulmonary nodes, divided in subaortic and para-aortic nodes*). Usually, enlarged lenticular nodes are found on the lateral side of the superior vena cava (Barthels' azygocaval node), between the latter and the ascending part of the aorta (interaorticocaval node) and between the aortic arch and the pulmonary trunk (Engel's aorticopulmonary node, also known as the ligamentum arteriosum node). Receiving their afferents from the thymus, the thyroid gland, the pericardium and the lateral diaphragmatic nodes, these anterior mediastinal nodes give rise to efferent

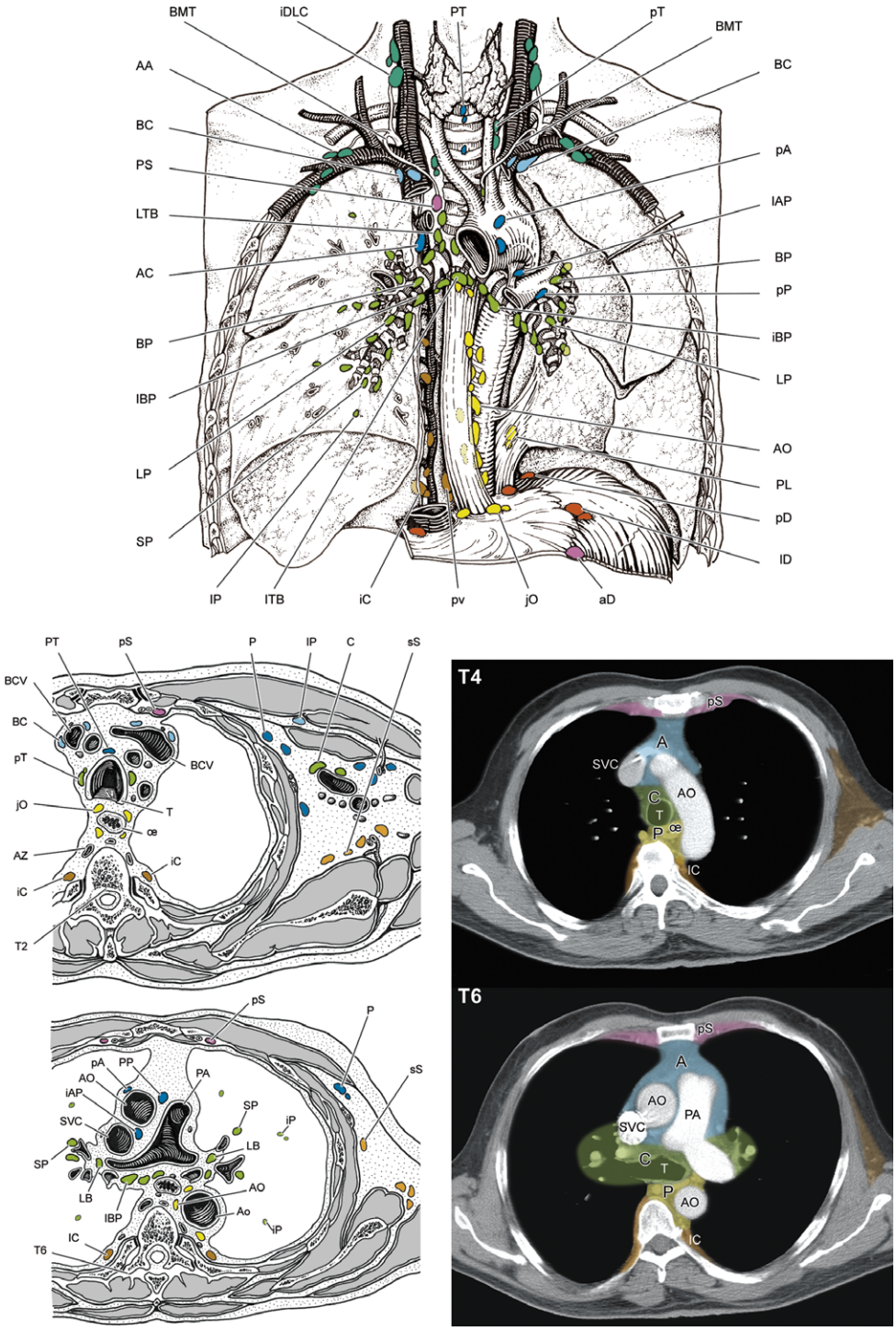

Fig. 3. Lymphatic nodes of the thorax. Anterior view of the chest showing the distribution of the thoracic node groups and levels. Corresponding target volumes are indicated on anatomical and CT sections through the upper and lower parts of the thorax. Node groups of the parietal system and of the anterior, central and posterior visceral pathways are indicated by different colours, matching those of the corresponding target areas: *AA, apical axillary n.; AC, azygocaval n. (Barthels'); aD, anterior diaphragmatic n.; AO, aortico-oesophageal n.; BC, brachiocephalic n.; BMT, bronchomediastinal trunk; iAP, interaortopulmonary n. (Engels'); iBP, interbronchial pulmonary n.; IC, intercostal n.; iDLC, inferior deep lateral cervical n.; iP, intrapulmonary n.; jO, juxtaoesophageal n.; lD, lateral diaphragmatic n.; LP, lobar pulmonary n.; LTB, superior laterotracheobronchial n.; P, pectoral n.; pA, pre-aortic n.; pD, posterior diaphragmatic n.; PL, pulmonary ligament n.; pP, prepulmonary n.; pS, parasternal n.; pT, paratracheal n.; pv, prevertebral n.; SP, segmental pulmonary n.; sS, subscapular n.* Key anatomical structures used to delineate the target volumes are as follows: *the aorta (Ao), pulmonary arteries (PA), superior vena cava (SVC), brachiocephalic veins (BCV), tracheobronchial tree (T) and the oesophagus (Oe). The target volumes are indicated as follows: the parasternal (PS), brachiocephalic (BC), intertracheobronchial (ITB), posterior mediastinal (PM) and intercostal (IC) areas.*

ducts which unite with those from the tracheobronchial nodes to form the bronchomediastinal trunk [2,19].

The *tracheobronchial nodes* are concentrated around the tracheal bifurcation and include five different groups which frequently contain the largest nodes of the body: the *paratracheal nodes* (*level 2: upper paratracheal nodes)* on the lateral sides of the trachea; the superior (latero) tracheobronchial nodes (*level 4: lower paratracheal, including azygocaval nodes*), situated in the angles between the trachea and the right and left main bronchi; the inferior (inter)tracheobronchial nodes (*level 7: subcarinal nodes*), located below the carina between the two main bronchial stems, the bronchopulmonary nodes (*level 10: hilar nodes*) in the hilum of each lung, and the intrapulmonary nodes (*levels 11–14: interlobar, lobar, segmental, and subsegmental nodes*), scattered within the central lung substance inside the divisions of the lobar, segmental and subsegmental branches of the bronchial tree [9,19]. The afferent vessels of the tracheobronchial nodes drain the lymph from the superficial (subpleural) and deep (peribronchial) networks of the lung, and also from the thoracic part of the trachea and the heart [2,14]. Together with those of the brachiocephalic group their efferents constitute the right and left bronchomediastinal trunks [19].

The *posterior mediastinal nodes* are spread within the posterior mediastinal fat, behind the trachea *(level 3: retrotracheal nodes*) then behind the pericardium, along the pulmonary ligament (*level 9: pulmonary ligament nodes*), and around the aorta and the oesophagus (*level 8: perioesophageal nodes, located below carina and often divided as middle – level 8M – and lower – level 8L – paraoesophageal nodes*). Receiving afferent vessels from the posterior part of the pericardium, the oesophagus and the posterior diaphragmatic nodes, they send efferents which mostly terminate in the thoracic duct, although some may end in the tracheobronchial chain [2,13,17].

Functional drainage pathways

Of immediate interest in understanding the way in which intrathoracic tumours are disseminated, the lymph nodes of the chest and their connecting vessels are arranged in three main ascending streams [8]:

The *anterior stream* is located in the anterior mediastinum. Including the xiphoid, parasternal and brachiocephalic nodes, it may become invaded as a result of the dissemination of breast, thyroid, or thymic tumours.

The *central stream* occupies the middle part of the mediastinum. Linked inferiorly to the lateral diaphragmatic nodes, it is formed by the successive subgroups of tracheobronchial nodes. Immediately adjacent to the respiratory tree, this main drainage pathway of the thoracic viscera represents the usual route of dissemination for lung cancers, but also for malignant tumours of the oesophagus.

The *posterior stream* runs behind the heart, in the narrow fatty space of the posterior mediastinum. Grouping the posterior diaphragmatic nodes and the posterior mediastinal nodes arranged in a continuous chain around the aorta and the oesophagus, it mostly ends in the thoracic duct. Its metastatic involvement is usually observed in cases of oesophageal cancer.

Although each represents an individual preferential pathway of lymphatic dispersion, the anterior, central and posterior mediastinal chains described herein are not completely separated from one another [2,8]. In the superior mediastinum, the terminal ducts of the anterior and central chains unite to give rise to an ascending common bronchomediastinal trunk (joining the low end of level IV of the head and neck region), while the posterior chain remains isolated, mainly connected to the thoracic duct [14,17]. On the contrary, the posterior and central pathways may encounter one another inferiorly since the lower perioesophageal nodes send divergent efferent vessels that end either in the inferior tracheobronchial nodes or in the thoracic duct [15,19]. Finally, it should be noted that both anterior and posterior pathways are connected by transdiaphragmatic channels with the parietal lymphatics of the peritoneal cavity: they may thus become involved in the spread of intra-abdominal tumours [17]. Along the lower oesophagus, in the direction of the cardia, lymph nodes (*level 8L: lower paraoesophageal*) may drain either cranially along the posterior mediastinal stream following the thoracic part of the oesophagus, or caudally, in the direction of the abdomen, through the paracardial nodes (*level 16*) and left gastric nodes (*level 17*), readily reaching the coeliac nodes (*level 20*) and the thoracic duct [6]. The lymphatic vessels draining the lower oesophagus give thus rise to a highly anastomotic network, linked cranially to the multiple node stations of the posterior mediastinal chain but also showing an alternative route with less resistivity in the direction of the thoracic duct through a shorter descending abdominal pathway. This fact presumably explains why intra-abdominal nodes along the lesser curvature are so easily invaded by oesophageal cancer.

Delineation of lymph node areas

On transverse sections of the chest, the lymphatic target volumes can be delineated according to the following anatomical landmarks (Fig. 3).

The *parasternal lymphatic area* is a lenticular laminar plane bounded anteriorly by the deep surface of the sternum and anterior intercostal spaces and dorsally by the transversus thoracis muscle. It extends from the xiphoid process upwards to the sternoclavicular joints with the internal thoracic artery as a central anatomical landmark.

The *brachiocephalic lymphatic area* (anterior area I) occupies the anterior mediastinal fat, in front of the large supracardiac vessels. Anteriorly facing the posterior aspect of the sternum, this volume is bounded laterally by the anterior parts of the right and left mediastinal pleurae. Caudally it disappears nearly below the level of the sixth thoracic vertebra and cranially it communicates through the thoracic inlet, alongside the carotid arteries and internal jugular veins, with the lower part of the cervical jugulocarotid areas. Conventionally, the inferior edge of clavicle can be used as landmark to trace the limit between these intrathoracic and deep cervical areas. Taking the brachiocephalic vein, the aortic arch and the pulmonary trunk as

successive anatomical landmarks, this volume can be divided into supra-aortic (area Ia), pre-aortic (area Ib) and subaortic (area Ic) stages which, respectively, contain the upper (*level 1: upper mediastinal*), middle (*level 6: pre-aortic*) and lower (*level 5: aortopulmonary*) anterior mediastinal lymph node groups [8]. The level 1 for thoracic staging is adjacent to the level VI of the head and neck region. However, these levels are not connected, as they both drain directly into the central venous system (see part I of the present article).

The *peritracheobronchial area* (central area II) is centered around the thoracic trachea and the main bronchi. Its anterior and posterior limits can be defined as running, respectively, along the posterior aspect of the superior vena cava and aortic arch anteriorly and along the ventral aspect of the oesophagus posteriorly. Delineated by the middle parts of the mediastinal pleurae, its lateral boundaries include the right and left pulmonary hila which enter into both lungs [8]. Inferiorly, this area does not extend below the level of the sixth thoracic vertebra, but includes all the node groups associated with the trachea (*level 2: upper paratracheal, level 4: lower paratracheal and level 7: subcarinall*) and with the origin of the bronchial tree (*level 10: tracheobronchial or hilar*). Using the aortic arch, the tracheal bifurcation as successive boundary landmarks, it may be dived into three successive stages containing the upper (area IIa), middle (area IIb) and lower (area IIc) peritracheobronchial lymph node stations. Outside the mediastinal fatty space and inside the parenchyma of each lung, this area spreads into the lateral pulmonary volumes which include two additional *right and left pulmonary areas* (intrapulmonary areas IVR and IVL), containing the multiple successive lymph node stations scattered inside the lungs (*levels 11: interlobar, 12: lobar, 13: segmental, and 14: subsegmental*).

The *posterior mediastinal area* is a narrow fatty channel located behind a plane running along the posterior aspect of the heart caudally and along the anterior surface of the oesophagus cranially. It is bounded by the ventral aspect of the vertebral column posteriorly, and laterally by the dorsal part of the mediastinal pleurae. This volume contains the thoracic oesophagus, the descending aorta, both azygos and hemi-azygos veins and between these landmarks, the thoracic duct and the posterior mediastinal nodes (*level 3: retrotracheal, levels 8M and 8L: middle and lower paraoesophageal, levels 9 of the pulmonary ligaments and level 15: diaphragmatic*). Using the tracheal bifurcation and the pulmonary hila as successive boundary landmarks, it may be divided into three successive stages containing the upper (area IIIa), middle (area IIIb) and lower (area IIIc) perioesophageal lymph node stations. Posterolateral extensions on both sides of the vertebrae up to the costal angles allow it to also include the posterior intercostal node groups [8], located along the proximal course of the posterior intercostals vessels and on the medial aspect of the thoracic sympathetic nerve chains.

Table 1 summarizes the here described simplified functional delineation of the three major chest visceral lymph node areas (I—II—III), emphasizing their critical anatomical landmarks and correlating their successive stages (a, b and c) with the corresponding levels listed in the AJCC and UICC node classifications.

Lymphatics of the abdomen

Following the same arrangement as that in the thorax, the lymphatics of the abdomen are divided into parietal and visceral vessels and nodes, and, respectively, drain

Table 1
Visceral node groups of the chest, with corresponding surgical levels and target areas for conformal radiotherapy (nodal CTV)

Node groups	AJCC levels	Area	Location	Anatomical landmarks
Anterior medistinal area (brachiocephalic, I)				
Brachiocephalic (supra-aortic)	*Level 1*	Ia	T1—T2	Along brachiocephalic veins
Pre-aortic	*Level 5*	Ib	T3	In front of aortic arch
Aortopulmonary (sub-para aortic)	*Level 6*	Ic	T4	Around ascending aorta and pulmonary arteries
Central mediastinal area (peritracheobronchic, II)				
Upper paratracheal	*Level 2*	IIa	T1—T2	Along trachea, above aortic arch
Lower paratracheal (laterotracheobronchic)	*Level 4*	IIb	T3	Along trachea, behind aortic arch (L) and below azygos arch (R)
Subcarinal (intertracheobronchic)	*Level 7*	IIc	T4	Around tracheal bifurcation
Pulmonary hilar (bronchopulmonary)	*Level 10*	IIc	T5—T6	Along main bronchus at hilum
Posterior mediastinal area (perioesophageal, III)				
Retrotracheal (upper post. Mediastinum)	*Level 3*	IIIa	T1—T4	Behind trachea
Middle paraoesophageal	*Level 8M*	IIIb	T5—T6	Below carina, facing pulmonary hilum
Lower paraoesophageal	*Level 8L*	IIIc	T7—T11	Below pulmonary hilum
Pulmonary ligament	*Level 9*	IIIc	T7—T9	Below hilum, facing left atrium
Diaphragmatic	*Level 15*	IIIc	T10—T11	Behind vertical part of diaphragm
Lateral pulmonary areas (right and left intrapulmonary)				
Interlobar	*Level 11*	IVa	—	Long main bronchus, in lung
Lobar	*Level 12*	IVb	—	Central position in lung, along lobar bronchi
Segmental	*Level 13*	IVc	—	Medial position in lung, along segmental bronchi
Subsegmental	*Level 14*	IVd	—	Peripheral position in lung, along distal airways

the walls and contents of the abdominal cavity. As a general rule, they all follow the course of the parietal and visceral branches of the abdominal aorta and they all return – except for some lymphatics arising from the liver – into the venous bloodstream via the thoracic duct [12,15]. Before reaching the latter, most of them are interrupted by very large retroperitoneal nodes scattered around the inferior vena cava and the aorta, commonly described as the terminal lumbo-aortic nodes [19,20].

Parietal vessels and nodes

The *superficial parietal lymphatic vessels* of the abdominal wall drain the lymph from the anterior and posterior abdominal skin and subcutaneous tissue upwards into the pectoral and subscapular axillary nodes, respectively (Fig. 2). Nevertheless, the low abdominal integuments located below the umbilicus are supplied by descending lymph vessels which terminate in the superficial inguinal nodes [17].

The *deep parietal vessels* originate from the muscles and fasciae of the abdominal wall. Running in the subperitoneal adipose tissue, they converge superiorly in a few small inferior diaphragmatic nodes and inferiorly they follow the deep inferior epigastric vessels to join the external iliac nodes. Posteriorly, they cross the quadratus lumborum and the psoas to end in the lateral or posterior lumbo-aortic nodes [12,19].

Visceral vessels and nodes

Arising from the various abdominal organs, the visceral lymphatic vessels pass through several outlying nodes firstly located close to the viscera, then occupy an intermediate position in the peritoneal ligaments and mesos. Finally, they reach larger groups of nodes associated with the major paired or uneven branches of the abdominal aorta, and terminate in the lumbar peri-aortic nodes (Fig. 4).

The *lumbar peri-aortic nodes* include four groups of nodes which are not clearly differentiated from each other topographically, although functionally each of them possesses a specific lymphatic territory. These four groups are divided into pre-aortic nodes, right and left lateral aortic nodes, and post-aortic nodes [20].

The *median pre-aortic nodes* drain the lymphatics of the digestive tract running along the ventral branches of the abdominal aorta. Their efferents form the intestinal trunks which open into the cisterna chyli [12,14].

On both sides the *lateral aortic nodes* receive efferent vessels arising from the common iliac nodes as well as terminal lymphatic collectors originating along the lateral branches of the aorta, from the kidneys, the suprarenal glands and the male or female gonadic glands. Therefore they constitute the main terminal group of nodes of all the abdominal or pelvic viscera of the urogenital system. They give rise to several large efferent vessels which constitute the right and left lumbar trunks, ending on both sides in the inferolateral corners of the cisterna chyli [12,17].

The *post-aortic nodes* do not possess a specific lymphatic territory. Initially described as mostly collecting the posterior deep parietal lymph vessels, they are now more accurately regarded as functionally linked to the lateral aortic nodes and share the same drainage area. Obviously, they never receive direct visceral afferents and have to be considered as additional relays of the previous groups of nodes before they reach the thoracic duct [15,19].

The pre-aortic group of nodes and their digestive affluents

The pre-aortic nodes are located immediately on the anterior surface of the abdominal aorta, forming a discontinuous chain divided into three distinct masses, respectively, grouping the coeliac, superior mesenteric and inferior mesenteric nodes, closely associated with the origin of the corresponding arteries [19].

The *coeliac nodes* (*level 20* in [6]) are usually two or three in number and surround the coeliac trunk at the level of the 12th thoracic vertebra. They collect the lymphatics from the stomach, duodenum, the major part of the liver, the gallbladder, pancreas and spleen. Their outlying intermediate nodes, located close to these organs and around their supplying blood vessels, are arranged in three main sets: the gastric, hepatic and pancreaticosplenic node groups [8,17].

The *gastric nodes* (*level 17* in [6]) are situated along the arterial vessels running along the lesser and greater curvatures of the stomach. Therefore, they are distinguished as *right* and *left gastric nodes* (*17R and 17L*) which are located in the lesser omentum on the lesser curvature of the stomach, or as *right* and *left gastro-epiploic nodes*, which lie between the two sheaths of the greater omentum in the lower part of the great curvature of the stomach. The upper nodes of the left gastric chain rest against the cardia and collect the lymph from the abdominal part of the oesophagus. Although they drain mainly into the coeliac group of aortic nodes, these *paracardial nodes* (*level 16* in [6]) may also have some efferent vessels which extend to the lower posterior mediastinal lymph nodes. Below the central part of the stomach, the right gastro-epiploic nodes are relayed by a group of four to five *pyloric nodes* which lie close to the division of the gastroduodenal artery and receive afferent vessels originating from the pylorus but also from the first part of the duodenum and from the head of the pancreas. The efferent vessels of these pyloric nodes usually follow the course of the gastroduodenal artery, crossing the first part of the duodenum posteriorly to join the coeliac group of pre-aortic nodes. Alternatively however, they may pass in front of the horizontal part of the duodenum to join the superior mesenteric nodes.

The *hepatic nodes* (*level 18* in [6]) form a chain of three to six nodes which are situated along the course of the hepatic artery. The first nodes are located at the origin of the artery and consequently correspond to the superior border of the pancreas. The following nodes are distributed on the anterior surface of the portal vein, on the anterior border of Winslow's epiploic foramen. The upper nodes finally occupy the hilum of the liver, randomly distributed around the right and left divisions of the hepatic artery. One of these nodes, however, has a fairly constant location at the junction of the cystic and common bile ducts near the neck of the gallbladder: it is known as Quenu's *cystic node*. Commonly, the hepatic nodes receive afferents from the liver, bile ducts and gallbladder, but also from the stomach,

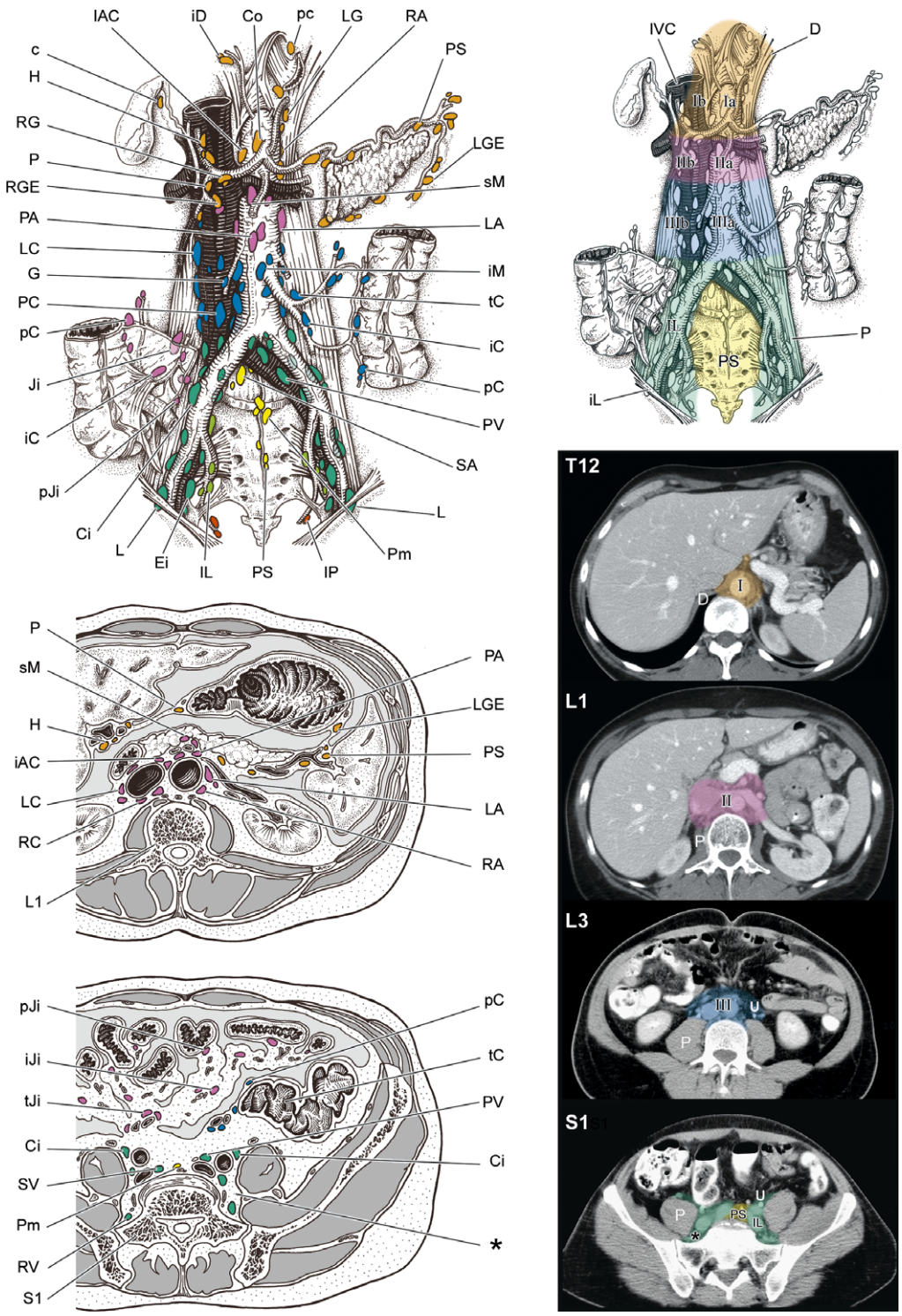

Fig. 4. Lymphatic nodes of the abdomen. Anterior view of the abdominal blood vessels and satellite lymph node groups. The corresponding target volumes are indicated on anatomical and CT sections through the upper, middle and lower parts of the abdominal cavity. Median and lateral groups of the lumbar peri-aortic nodes and related juxtavisceral nodes of the successive abdominal levels (I—III) are indicated by different colours, matching those of the corresponding target areas. *C, cystic n. (Quenu's); Co, coeliac n.; G, gonadic n.; H, hepatic n.; IAC, interaorticocaval n.; IC, ileocolic n.; iC, intermediate colic n.; iD, inferior diaphragmatic n.; iM, inferior mesenteric n.; Ji, jejunoileal n.; subclassified as para-intestinal (p), intermediate (i) and terminal (t); LA, lateroaortic n.; LC, laterocaval n.; LG, left gastric n.; LGE, left gastro-epiploic n.; p, pyloric n.; PA, pre-aortic n.; PC, precaval n.; pC, paracolic n.; pc, paracardial n.; RA, retroaortic n.; RC, retrocaval n.; RG, right gastric n.; RGE, right gastro-epiploic n.; sM, superior mesenteric n.; tC, terminal colic n.* Key anatomical structures to delineate the target volumes are as follows: *the aorta (Ao), inferior vena cava (IVC), iliac vessels (IV), ureters (U), diaphragmatic pillars (D) and the psoas muscles (P).* The asterisks indicate Cuneo's and Marcille's fossae. Inferiorly, the lymphatics of the abdomen are continuous with those of the lateral and central chains of the pelvis, emphasized with the same colours and legends as in the figures of part 3 in this series.

duodenum and pancreas; their efferents all pass through the pre-aortic nodes.

The *pancreaticosplenic nodes* (*level 19* in [6]) are associated with the splenic artery and are consequently related to the upper border and posterior aspect of the pancreas. The largest of these nodes, described by Cunéo, is located medially behind the body of the pancreas. Laterally, one or two smaller nodes are located in the pancreaticosplenic ligament, near the hilum of the spleen. Collecting afferent vessels running alongside the branches of the splenic artery, these nodes drain the spleen, the tail and the body of the pancreas and the fundus of the stomach. Their efferents end in the coeliac group of pre-aortic nodes [14].

The *superior mesenteric nodes* form a large mass of lymphatic tissue surrounding the origin of the superior mesenteric artery on the anterior aspect of the aorta. Located behind the pancreas at the level of the first lumbar vertebra, they are almost continuous, without a clear line of demarcation, with the large mesenteric lymph nodes situated at the root of the mesentery. Their numerous afferent vessels drain the mesenteric and ileocolic lymph nodes, and in this manner the last parts of the duodenum, the small intestine and the right part of the colon [17,20].

The *mesenteric lymph nodes* are approximately 100–150 in number. They are usually distributed within the mesenteric fat and constitute three successive relays: the most peripheral nodes are known as the *juxta-intestinal mesenteric nodes* and lie close to the intestinal walls between the terminal jejunal and ileal arteries; the second group of nodes occupies an intermediate position within the mesentery between the primary or secondary loops of the superior mesenteric artery; the last nodes, which are less numerous but larger, are located along the main stem of this vessel, near the mesenteric root, and constitute the *central mesenteric nodes* [12].

The *ileocolic nodes* constitute a continuous chain of about 20 nodes around the ileocolic artery, and are sometimes artificially differentiated into upper and lower ileocolic nodes. At the point where the vessel divides into its terminal branches, the lower nodes form three subgroups known as the *recurrent ileal* and *anterior* or *posterior ileocolic nodes*, which occupy the corresponding ileocaecal folds. A single node is usually found in the meso-appendix [12].

The *inferior mesenteric nodes* usually consist of two large elongated nodes symmetrically located on each side of the origin of the inferior mesenteric artery. In these lymph nodes situated at the level of the third lumbar vertebra terminate the lymphatic trunks originating from the upper part of the rectum and from the left half of the colon. Moreover, these vessels have already passed through three or four successive relays which are very similar to those of the small intestine: among these are the *epicolic nodes*, which are small nodules embedded in the walls of the colon itself. They are connected to the *paracolic nodes* which are located along the mesenteric borders of the colon and followed by the *intermediate colic nodes*, located along the middle and left colic arteries. Their efferents finally drain into the *terminal colic nodes*, along the main stem of the inferior mesenteric artery. An identical nodal arrangement is observed in the ascending and transverse parts of the colon, although the terminal collectors end in the ileocolic group of superior mesenteric nodes [12,15,17].

The lateral aortic lymph nodes and their urogenital affluents

The *left lateral aortic nodes* form an almost continuous vertical chain on the left side of the abdominal aorta. Dorsally, this chain lies on the vertebral attachments of the psoas muscle and on the left pillar of the diaphragm. Laterally facing the sympathetic nervous trunks, it is crossed on its anterior aspect by the left renal vessels [12].

The *right lateral aortic nodes* are located either in front of the inferior vena cava or behind it. A few of them lie on the lateral side of the vein or seem to be interposed between the latter and the aorta. According to their various locations, the right lateroaortic nodes can be characterized as *precaval*, *laterocaval* or *postcaval nodes*. However, they have the same topographical relationships as those of the left lateral aortic nodes [15,17].

On both sides, the lateral aortic nodes receive afferent vessels from all the structures supplied by the posterior and lateral paired branches of the abdominal aorta and also collect the ascending lymphatic trunks arising from the pelvis through the common iliac nodes. In addition to the posterior parietal vessels, their major affluents are the following:

The *lymphatics from the adrenal glands* running along the renal, suprarenal and inferior diaphragmatic vessels.
The *lymphatics from the kidneys*, also draining the perirenal fat capsule and the abdominal part of the ureter, which enter the nodes located near the first lumbar vertebra.
The *gonadic lymphatics* arising from the testes in the male, or from the ovaries and lateral part of the uterine tubes in the female [11].

All these afferent vessels form tortuous networks around the suprarenal, renal and gonadic vessels. Furthermore, they issue directly from their respective organs without making any relay in the intermediate nodes. Finally, among the efferent vessels leaving the lateral aortic nodes, some send multiple connections to the pre- and post-aortic nodes, thereby giving rise to a rich peri-aortocaval lymphatic plexus, partially bypassing the main lumbar collecting trunks.

Functional drainage pathways

Because of the complex three-dimensional organisation of the abdominal lymphatic network, the major drainage pathways are difficult to delineate for the different visceral groups (Fig. 4).

Widely distributed between the immediate vicinity of the various derivatives of the alimentary tract and the origin of their successive supplying vessels, the *digestive lymphatic* pathways occupy the multiplanar spaces of their mesos and peritoneal ligaments. Running between the complex arrangement of organs, these pathways cannot be easily confined in a simple volume with well-defined boundaries [8]. Distally however, they all converge towards a *central*

Table 2
Drainage of the intra-abdominal organs in the various anatomical levels of Fig. 4

Levels	I		II		III	
Sublevels	Ia	Ib	IIa	IIb	IIIa	IIIb
Organs	Liver Stomach Spleen Bile duct	Adrenals Kidneys (upper pole)	Small bowel Right colon Pancreas and duodenum	Kidneys Ovaries Testis	Left colon Sigmoid Rectum	Ovaries Testis
Location	In front of T12		In front of L1		In front of L3	
Anatomical landmarks	Around big vessels aorta, IVC (median)	Anterior to phren. pilar and psoas m. (lateral)	Around big vessels aorta, IVC (median)	Anterior to psoas muscle (lateral)	Around big vessels aorta, IVC (median)	Anterior to psoas muscle (lateral)

All levels labeled ''a'' are median and drain the intra-peritoneal organs. All levels labeled ''b'' are lateral and drain retroperitoneal organs and structures.

ascending axis, giving rise to a median pre-aortic pathway. The latter longitudinal chain can be divided into three successive functional levels:

The *coeliac level* (Ia, corresponding to *level 20* in [6]) is located in front of the T12 vertebra. It receives the terminal lymphatic pathways of all the viscera located in the supra-mesocolic part of the peritoneal cavity. Consequently, its metastatic involvement is thus usually observed in tumours of the liver, bile ducts, stomach, abdominal oesophagus or pancreas.
The height of the *superior mesenteric level* (IIa) corresponds to that of the L1 vertebra. Receiving the lymphatic pathways from the small intestine and right hemicolon, it may also be invaded in cases of pancreaticoduodenal cancer.
The height of the *inferior mesenteric level* (IIIa) is situated in front of the L3 vertebra and may show enlarged metastatic nodes as a result of the lymphatic spread of malignant tumours of the left hemicolon or upper part of the rectum.

More precisely located in the retroperitoneal space, the *genito-urinary lymphatic pathways* on both sides of the abdominal aorta form two *lateral ascending chains* facing the psoas muscles posteriorly and the right and left diaphragmatic pillars. As in the case of the central digestive axis, the anatomical landmarks of the T12, L1 and L3 vertebrae can be used to define the three functional levels (Ib, IIb and IIIb) where primary metastatic nodes of suprarenal, renal and gonadic tumours may be, respectively, found [8].

Table 2 summarizes the drainage of the intra-abdominal organs in the various anatomical levels of Fig. 4.

Delineation of lymph node areas

As an extension of the previous considerations, it is difficult to include all the juxtavisceral or intermediate groups of abdominal nodes and interposed lymph vessels within simple geometric compartments with well-defined anatomical boundaries. However, the possibility exists of more accurately delineating the three-dimensional space that contains the terminal lumbar peri-aortic nodes, their efferent trunks, the cisterna chyli and the abdominal part of the thoracic duct (Fig. 4).

On radiological CT or MR sections, the so-obtained *lumbar peri-aortic lymphatic area* is bounded dorsally by the anterior aspect of the vertebral column and extends laterally towards the lateral borders of the psoas muscles and, more superiorly to the edges of both pillars of the diaphragm. Ventrally, its anterior limit corresponds to the posterior peritoneal lining of the omental bursa, then to the posterior surface of the pancreas, and finally to the root of the mesentery [8]. This longitudinal volume extends from the 12th thoracic vertebra downwards to the fourth lumbar vertebra, and in addition to the various lumbar groups of nodes belonging to levels I, II and III, includes the abdominal aorta, the inferior vena cava, the ureters, the gonadic, renal and suprarenal vessels and the sympathetic nerves of the coeliac plexus, all embedded within the retroperitoneal fat.

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References

[1] Berg JW. The significance of axillary node levels in the study of breast cancer. Cancer 1955;63:776—8.
[2] Caplan I. Anatomical review of the lymph nodes of the mediastinum. Surg Radiol Anat 1990;12:9—18.
[3] Gregoire V, Coche E, Cosnard G, et al. Selection and delineation of lymph node target volumes in head and neck conformal radiotherapy. Proposal for standardizing terminology and procedure based on the surgical experience. Radiother Oncol 2000;56:135—50.
[4] Kajitani T. Japanese research society for the study of gastric cancer. The general rules for gastric cancer study in surgery and pathology. Jpn J Surg 1981;11:127—45.
[5] Kirikuta IC. Target volume selection and delineation in breast cancer conformal radiotherapy. In: Gregoire V, Scalliet P, Ang KK, editors. Clinical target volume in conformal and intensity modulated radiotherapy. A clinical guide to cancer treat-

ment. Berlin, Heidelberg, New York: Springer Verlag; 1998. p. 121–43.
[6] Korst RJ, Rush VW, Venkatraman E, et al. Proposed revision of the staging classification for esophageal cancer. J Thoracic Cardiovasc Surg 1998;3:660–70.
[7] Kubik S. Efferente LymphgefäBe und die regionale Lymphnoten der Brustdrüse. In: Földi, M, Kubik, S, editor. Lehrbuch der Lymphologie. Ath ed. Stuttgart, Jean, Lübeck, Ulm: Fischer; 1999. p. 137–52.
[8] Lengele BG. The lymphatic system. In: Gregoire V, Scalliet P, Ang KK, editors. Clinical target volume in conformal and intensity modulated radiotherapy. A clinical guide to cancer treatment. Berlin, Heidelberg, New York: Springer Verlag; 2004. p. 1–36.
[9] Lengele BG, Hamoir M, Scalliet P, Gregoire V. Anatomical bases for the radiological delineation of lymph node areas. Major collecting trunks, head and neck. Radiother Oncol 2007; doi:10.1016/j.radonc.2007.02.009.
[10] Moutain CF, Dressler CM. Regional lymph node classification for lung cancer staging. Chest 1997;111:1718–23.
[11] Plentl AA, Friedman EA. Lymphatic system of the female genitalia. The morphologic basis of oncologic diagnosis and therapy. Philadelphia: Saunders; 1971.
[12] Poirier P, Cuneo B, Delamere G. The lymphatics. Westminster: Archibald Constable & Co. Ltd.; 1903.
[13] Riquet M, Pimpec-barthes LE, Hidden G. Lymphatic drainage of the pericardium to the mediastinal lymph nodes. Surg Radiol Anat 2001;23:317–9.
[14] Rouviere H, Tobias MJ. Anatomy of the human lymphatic system. Ann Arbor: Edwards; 1938.
[15] Sappey PC. Des vaisseaux lymphatiques. In: Sappey PC, editor. Traité d'anatomie descriptive, vol. 2. Paris: Delahaye A, Lecrosnier E; 1888. p. 731–842.
[16] Senan S, Van Sörnsen De Koste j, Samson M, et al. Evaluation of a target contouring protocol for 3D conformal radiotherapy in non-small-cell lung cancer. Radiother Oncol 1999;53:247–55.
[17] Testut L. Des lymphatiques. In: Testut L, editor. Traité d'anatomie humaine, vol. 2. Paris: Doin; 1893. p. 267–308.
[18] Valentini V, Dinapoli N, Nori S, et al. An application of visible human database in radiotherapy: tutorial for image guided external radiotherapy (TIGER). Radiother Oncol 2004;70:165–9.
[19] Warwick R, Williams P. Topography of the lymph nodes and vessels. In: Gray's anatomy. Edinburgh: Longman; 1973. p. 727–44.
[20] Whitmore I. Lymphoid system. In: Federative Committee on Anatomical Terminology – terminologica anatomica. Stuttgart: Thieme Verlag; 1998. p. 100–3.