REVIEW

The evolution of surgery in the management of neck metastases

L’evoluzione della chirurgia nelle metastasi linfonodali laterocervicali

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Key words
Neck • Lymph nodes • Neck dissection • Classification • History • Evolution

Summary
In spite of advancement in science, molecular medicine and target therapies, surgical treatment of metastases using different techniques, from selective neck dissection to extended radical neck dissections, form a major part in the management of neck metastases. This is due to the fact that, so far, there is no treatment more effective for resectable neck metastases, than surgery. Since most head and neck cancer patients die due to loco-regional progression of disease, and a very large majority of them do not live long enough to develop distant metastases, the status of neck lymph nodes remains the single most important prognostic factor, in these cases. In the 100 years since George Washington Crile described Radical Neck Dissection, we now have a much better understanding of the biological and clinical behaviour of neck metastases. This has ultimately led to the conservative approaches of selective neck dissections depending on the primary site of the tumour, type of tumour and the characteristic features of the metastases themselves. A search of the literature on neck lymph nodes and neck dissections, on the internet and in old publications, not available in the electronic media, has been carried out. Using this as the basis, we arranged, in sequence, the dates of various landmarks in the treatment of head and neck cancer related to neck dissections to emphasize the overall process of evolution of neck dissection thereby showing how the field of head and neck surgery has travelled a long way from radical neck dissection to its modifications and further to selective neck dissections and sentinel node biopsies. The present understanding of the patterns of neck metastases enables us not only to adequately treat the neck metastases, but also to diagnose metastases from unknown primaries. Therefore, depending on the site of the primary tumour, it is now easy to predict the most probable route of metastatic spread and vice versa. This has enabled us to adopt modified and selective neck dissections which have ultimately led to a dramatic reduction in morbidity and almost eliminated mortality due to neck dissection. In the near future, molecular diagnostics and targeted therapies for treating metastases should be able to further reduce the burden of head and neck cancer.

Riassunto
Nonostante l’avvento della medicina molecolare, la chirurgia (con le varie tecniche dagli svuotamenti radicali a quelli selettivi) rappresenta ancora oggi il più importante presidio terapeutico delle metastasi linfonodali nei carcinomi squamocellulari della testa e collo. Esse infatti rappresentano il fattore prognostico più importante in queste neoplasie. Questa review si propone di illustrare il percorso fatto dai chirurghi e dagli oncologi cervico-facciali nei cent’anni trascorsi dalla pubblicazione di Crile, che per primo descrisse tecnica e risultati dello svuotamento laterocervicale. Inizialmente, venivano praticate tecniche chirurgiche demolitive; successivamente sono state utilizzate metodiche più rispettose della funzione. Negli ultimi anni lo studio del linfonodo sentinel e la mappatura del flusso linfatico hanno permesso di meglio conoscere le vie di diffusione e di personalizzare la terapia delle aree linfatiche, riducendo la morbidità legata a questi interventi. Nel futuro, la diagnosi molecolare e le terapie mirate ci consentiranno di migliorare ulteriormente i risultati oncologici e funzionali.
In ancient times, Hippocrates and Aristotle mentioned the presence of lymph vessels. In the following centuries, no mention was made of lymphatic vessels or nodes, until the 17th Century.

**Lymphatic network: Anatomical studies**

1622: the Italian anatomist, in Pavia, Gaspar Asellius (Fig. 1) rediscovered the lymphatic system. He demonstrated the functional relationship between food consumption and filling of mesenteric lymphatic vessels in dogs (Fig. 2).

1692: Antony Nuck studied the lymphatic network introducing mercury into the lymphatic vessels of cadavers.

1787: Paolo Mascagni published “Vasorum lymphaticorum corporis humani historia et iconographia”. This important publication focused on the first systematic description of the human lymphatic system.

1909: Poirer published a treatise on the human anatomy with a description of the lymphatic network.

1930: H.A. Trotter described the surgical anatomy of head and neck lymphatics, indispensable help for surgeons that perform neck dissections.

1938: H. Rouviere elaborated the classification of neck lymph nodes, based on the topographic anatomy of the neck, in a volume “Anatomy of human lymphatic system”, on which, still now, we base our clinical practice.

**Lymphatic network: functional studies**

In those same years, several Authors, as reported by Werner and by Wise, studied the lymphatic system from a functional point of view.

1840: A. Cooper found the presence of breast cancer cells in the lymphatic vessels, thereby demonstrating the lymphogenic spread of malignant tumours.

1860: R. Virchow, continuing Cooper’s studies, showed that lymph nodes form a barrier preventing dissemination of tumoural cells.

1865: H.F. Le Dran reproduced the work of Cooper and confirmed his conclusions.

Later, these studies were abandoned and only in the
last fifteen years have they been restarted thanks to the introduction, in clinical practice, of Sentinel Node Biopsy (SNB).

2000-2001: T. Soahib and F. Chiesa reported their experience in SNB, on head and neck squamous cell carcinoma (SCC), and proved its reliability.

2006: C. De Cicco published a paper on the use of dynamic lymphoscintigraphy (Lymphatic Mapping) to identify the nodes reached by the lymphatic stream from the tumour in order to tailor a selective dissection on each patient with clinically negative necks (cN0). About a third of the human lymph nodes are localized in the neck. Head and neck carcinomas mostly exhibit lymphogenic metastatic spread. Metastases in the neck are mostly due to a primary tumour arising in the head or neck region. The enormous amount of experience gained by surgeons worldwide has led to the understanding that patterns of metastatic spread of these cancers depend on the topography of the lymphatic system.

Neck dissection

Improvements in the knowledge of the nature of metastatic disease led surgeons to remove neck metastases and the first reports were published in the later part of the 19th Century. Since then, surgery still remains the main modality of treatment of neck metastases. The major steps are outlined below.

1847: J.C. Warren reported an experimental dissection of carcinoma in the neck.

1880: T. Kocher described the surgical removal of a tumour of the tongue en bloc with the regional lymph nodes using a mandibulotomy approach.

1885: H. Butlin described the resection of carcinoma of tongue with dissection of cervical lymph nodes.

1888: The Polish surgeon F. Jawdynski performed a radical neck dissection using a surgical technique similar to that described by G.W. Crile 18 years later. His paper was published in Polish, in a Polish journal, therefore only a few surgeons became acquainted with this technique.

1894: The Russian surgeon M. Regulskiy underlined the importance of removing neck lymph nodes, whatever their condition (metastatic or not), in cancer of the lower lip.

1901: J. Solis-Cohen emphasized the need for neck dissection irrespective of the presence or absence of clinically palpable metastases from laryngeal carcinoma.

1906: G.W. Crile (Fig. 3) described the technique of radical neck dissection. In his paper, he reported on 132 radical neck dissections in which the boundaries of resection were the clavicle, the strap muscles and the posterior border of the sternocleidomastoid muscle. He also removed the sternocleidomastoid muscle, posterior belly of the digastric muscle, internal jugular vein and accessory nerve but left the platysma intact. G.W. Crile’s experience was a milestone in the development of neck dissection in the 20th Century, because unlike Jawdyński’s report, his paper and his ideas spread rapidly all over the world.

1911: R.H. Vanakh, described the so-called “collar incision” for removal of carcinoma of the lower lip. Through this incision, he removed both the submandibular salivary glands, and submandibular and submental lymph nodes. This technique was later on referred to as Vanakh surgery.

1913: H. Morestin described an operation with a cutaneous access that he called “incision stellaire”. Unlike Crile, he preserved the sternocleidomastoid muscle, internal jugular vein and accessory nerve. He removed the upper jugular lymph nodes along the accessory nerve, now classified as level IIB.

Fig. 3. George Washington Crile.
ther Crile nor Morestin removed the posterior supraclavicular nodes (now level V).

1927: J. Roux-Berger described a technical variant of Crile’s operation: he removed the stylohyoid muscle and the posterior belly of the digastric muscle to obtain better access to the upper jugular chain and accessory nodes. R. Bernard emphasized the oncological role of Crile’s operation and underlined the importance of Morestin’s dissection enlarged to the accessory nodes.

In this period, Soviet surgeons developed good expertise in neck dissection and published several papers, the more important are outlined herewith:

1928: P.A. Hertzen performed neck dissections preserving the internal jugular vein and sternocleidomastoid muscle in cases without metastatic infiltration of these structures. He emphasized that, “for tongue cancer, taking into consideration the characteristic features of lymphatic flow and topographic anatomy of neck lymph nodes, all nodes along the internal jugular vein should be removed apart from removing all the tissue from the base of tongue”.

1929: N.N. Petrov published his experience on radical neck dissection in 32 patients with head and neck cancer and emphasized that surgery is more effective than radiotherapy in the management of neck metastases.

1940: I.E. Davydov treated laryngeal cancers preserving the internal jugular vein, sternocleidomastoid muscle and accessory nerve if there was no metastases involving these structures. He removed only the lymph nodes above the intersection of the sternocleidomastoid muscle and omohyoid muscle, and left those at levels IV and V.

After the second world war, neck dissection was revisited both in Europe and in the USA:

1945: M. Dargent described bilateral neck dissection preserving the internal jugular veins as curative treatment.

1951: H. Martin emphasized the importance of neck dissections. He published the experience of 1450 radical neck dissections performed at the Memorial Hospital from 1928 to 1950. He was responsible for the wide dissemination of the radical neck dissection technique all over the world.

1960: E.A. Gould underlined the usefulness of intraoperative histological examination of nodes. He reported that in 1951, while performing a parotidectomy, he sent, for frozen section, a node which looked normal, located at the junction of the anterior and posterior branches of the facial vein. The histological report was “lymph node with metastatic tumour”. He called this node “Sentinel Node”. From then on intraoperative examination of the facial vein guided their decision whether to perform radical neck dissection during parotidectomy.

1962: O. Suarez, described functional neck dissection, now called modified radical neck dissection.
<table>
<thead>
<tr>
<th>Levels</th>
<th>Lymph node groups</th>
<th>Boundaries</th>
<th>Comments</th>
<th>Primary tumour site</th>
</tr>
</thead>
</table>
| IA     | Submental        | Superior – symphysis of mandible  
Lateral – anterior bellies of digastric muscles  
Inferior – body of hyoid bone | Only submental lymph nodes belong to this level | Lower lip, anterior part of oral cavity, floor of mouth, anterior portion of alveolar part of mandible |
| IB     | Submandibular    | Superior – body of mandible  
Anterior – anterior belly of digastric muscle  
Posterior – stylohyoid muscle  
Inferior – posterior belly of digastric muscle | When metastases are present in this level, the submandibular gland is also usually removed during neck dissection | Oral cavity, anterior portion of nasal cavity, soft tissues of the face, submandibular gland |
| IIA    | Upper jugular    | Superior – skull base  
Anterior – stylohyoid muscle  
Posterior – accessory nerve  
Inferior – horizontal plane defined by the inferior body of hyoid bone | The lymph nodes around the internal jugular vein in this region located anterior to the accessory nerve belong to this level | Oropharynx including retromolar region, soft palate, tonsils, thyroid gland |
| IIB    | Middle jugular   | Superior – horizontal plane defined by the inferior body of hyoid bone  
Anterior – medial border of the sternocleidomastoid muscle  
Posterior – lateral border of the sternocleidomastoid muscle, branches of cervical plexus  
Inferior – horizontal plane defined by the inferior border of cricoid cartilage | These lymph nodes are located around the internal jugular vein in this region | Oral cavity, oropharynx, nasopharynx, hypopharynx, larynx, thyroid gland |
| III    | Lower jugular    | Superior – horizontal plane defined by the inferior border of cricoid cartilage  
Anterior – medial border of the sternocleidomastoid muscle  
Posterior – lateral border of the sternocleidomastoid muscle, branches of cervical plexus  
Inferior – clavicle | These lymph nodes are located around the internal jugular vein in this region. The Virchow node which is significant for gastric cancer also belongs to this level | Hypopharynx, thyroid gland, larynx, cervical oesophagus, stomach |
| VA     | Posterior triangle | Superior – apex of convergence of the sternocleidomastoid and trapezius muscles  
Anterior – lateral border of the sternocleidomastoid muscle, branches of cervical plexus  
Inferior – clavicle | Lymph nodes along the lower portion of accessory nerve | Nasopharynx, oropharynx, skin of posterior neck, skin of the scalp |
| VB     | Anterior compartment | Superior – horizontal plane defined by the inferior border of cricoid cartilage  
Anterior – lateral border of the sternocleidomastoid muscle, branches of cervical plexus  
Posterior – anterior border of trapezius muscle  
Inferior – clavicle | Lymph nodes along the transverse artery and other supravacular nodes, except Virchow's node | Thyroid gland |
| VI     | Anterior compartment | Superior – hyoid bone  
Lateral – common carotid arteries  
Inferior – suprasternal notch | This group includes pre- 
paratracheal, prelaryngeal, 
precricoid, perithyroidal lymph nodes and the nodes along the recurrent laryngeal nerves | Thyroid gland, glottic, subglottic larynx, apex of piriform sinus, cervical oesophagus |
1967: E. Bocca described in detail the surgical steps of the functional neck dissection \(^{37}\); he led to this operation becoming popular all over the world \(^{38} \), \(^{39}\), and which is, today, usually defined as Suarez-Bocca technique.

1969: Two Soviet surgeons (A.I. Paches and G.V. Falileev) described the “Fascial compartment dissection of neck tissue” which corresponds to functional neck dissection \(^{40}\). Up to now, in the Russian speaking countries, the term “Fascial compartment dissection of neck tissue” is widely in use to define conservative functional surgery, even if all modified types of operations, from selective to extended neck dissections, are routinely performed, while “Crile’s operation” indicates a radical neck dissection.

1972: R. Lindberg published a study on the distribution of neck metastases; it was another landmark and formed the basis for further evolution of neck dissections \(^{41}\).

1981: J. Shah recommended modified neck dissection for N0 neck and radical neck dissection for clinically positive necks \(^{42}\).

1988: The American Academy of Otorhinolaryngology – Head and Neck Surgery (AAO-HNS) initiated the neck dissection classification project. An ad hoc committee of the newly formed American Head and Neck Society (AHNS) was convened to review, at regular intervals, the classification scheme \(^{22}\).

1990: J. Shah classified the deep lymph nodes of the neck into five different levels assigned Roman numerals from I to V \(^{43}\). This was another landmark, as the present classification of neck lymph nodes is fully based on that launched in this paper.

1991: AAO-HNS made the first attempt to standardize neck dissection terminology \(^{23}\). This classification added level VI to the topography of cervical lymph nodes earlier proposed by J. Shah, and included radical neck dissection, modified radical neck dissection, extended neck dissection and selective neck dissections which were subdivided into supraomohyoid, anterolateral, lateral and posterolateral neck dissections. The neck levels and their corresponding lymph node groups are shown in Figures 4 and 5, respectively, and the most common related primary sites of tumours are shown in Table I.

2002: The latest classification of neck dissections \(^{25}\) proposed by the AAO-HNS committee (Table II) is quite simple to understand and is based on the neck lymph node levels. It includes the following changes to the previous classification:

1. Any lymph node group outside the neck would be referred to by the name of that specific group, even though many Authors suggest defining the tracheo-oesophageal and superior mediastinal nodes as level VII.
2. Sublevels a and b were introduced in levels I, II and IV.
3. The structure(s) preserved in modified radical neck dissection should be specifically mentioned in surgical reports.
4. The levels removed in selective neck dissections should be quoted within brackets. Each dissection (Table II) should be defined by the levels removed instead of the traditional classification (supraomohyoid, lateral, posterolateral and anterior neck dissection).

### Table II. Classification of neck dissections (AAO-HNS) \(^{25}\).

<table>
<thead>
<tr>
<th>Surgery</th>
<th>Structures removed</th>
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</thead>
<tbody>
<tr>
<td>Radical Neck Dissection</td>
<td>Lymph node levels I-V, sternocleidomastoid muscle, internal jugular vein and accessory nerve</td>
</tr>
<tr>
<td>Extended Neck Dissection</td>
<td>Lymph node levels I-V, sternocleidomastoid muscle, internal jugular vein and accessory nerve + (plus) at least one lymphatic or non-lymphatic structure not sacrificed during radical neck dissection (parapharyngeal nodes, superior mediastinal nodes, perifacial nodes, carotid artery, hypoglossal nerve, vagus nerve, paraspinal muscles, etc.)</td>
</tr>
<tr>
<td>Modified Radical Neck Dissection</td>
<td>Radical neck dissection - (minus) at least one of the three major structures namely sternocleidomastoid muscle, internal jugular vein or accessory nerve. The structure preserved should be specifically named.</td>
</tr>
<tr>
<td>Selective Neck Dissection</td>
<td>At least one of the six lymph node levels/sublevels preserved. None of the structures namely sternocleidomastoid muscle, internal jugular vein and accessory nerve are sacrificed (the removed levels or sublevels should be mentioned within parentheses: I-III, II-VI, VI etc.)</td>
</tr>
</tbody>
</table>

### Conclusion

Knowledge of the patterns of metastatic spread of head and neck cancers, development of modern surgery, and advancement in imaging, cytology and...
molecular medicine permit us to individualize the treatment of patients. Since Crile’s publication, in 1906, head and neck surgeons and oncologists from all over the world have accumulated enormous experience in the management of neck metastases. In this period, a long journey has been undertaken from radical neck dissection to selective neck dissections, and sentinel node biopsies. Our present knowledge of patterns of neck metastases enables us to tailor treatment of neck metastases on each patient. This has ultimately led to a dramatic reduction in morbidity, with almost no mortality related to neck dissection. We believe that, in the near future, molecular diagnostics and targeted therapies will be able to reduce the burden of head and neck cancer.

References

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