

# Application of Network Analysis and Association Rule Mining for Visualizing the Lymph Node Metastasis Patterns in Esophageal Squamous Cell Carcinoma

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## Abstract

Understanding the patterns of lymph node (LN) metastases in esophageal squamous cell carcinoma (ESCC) is important for accurate staging and defining the extent of lymphadenectomy. This study clarified the patterns of LN metastases in ESCC using data mining techniques. 1,181 patients with LN metastases who underwent upfront esophagectomy for ESCC were analyzed. Network analysis and association rule mining (ARM) techniques were employed to visualize and quantify LN metastases according to the T stage (T1 vs. T2–4) and the primary lesion location. Network plots depicted the relationship between primary lesions and metastatic LNs, and mutual LN metastasis patterns. ARM metrics assessed connection strengths among LNs. Network analysis identified the most prevalent LN metastases at 106recR/L, 105–108–110, and 1–2–7, independent of the T stage and location. ARM indicated high metastases likelihood at 106recR/L for upper ESCC, 1–2–7 and 106recR for mid-ESCC, and 1–2–7 for lower ESCC. Mutual metastases analysis identified 106recR/L, 1–2–7, and 105–108–110 as common metastasis stations across all subgroups. Conviction showed that cervical LN metastasis occurred independently of 106recR/L. Data mining techniques elucidate the intricate patterns of LN metastases and the association between metastatic LNs in ESCC.

**Keywords:** Esophageal neoplasms; oncologic outcome; esophageal squamous cell cancer; lymph node metastases; network analysis; association rule mining

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