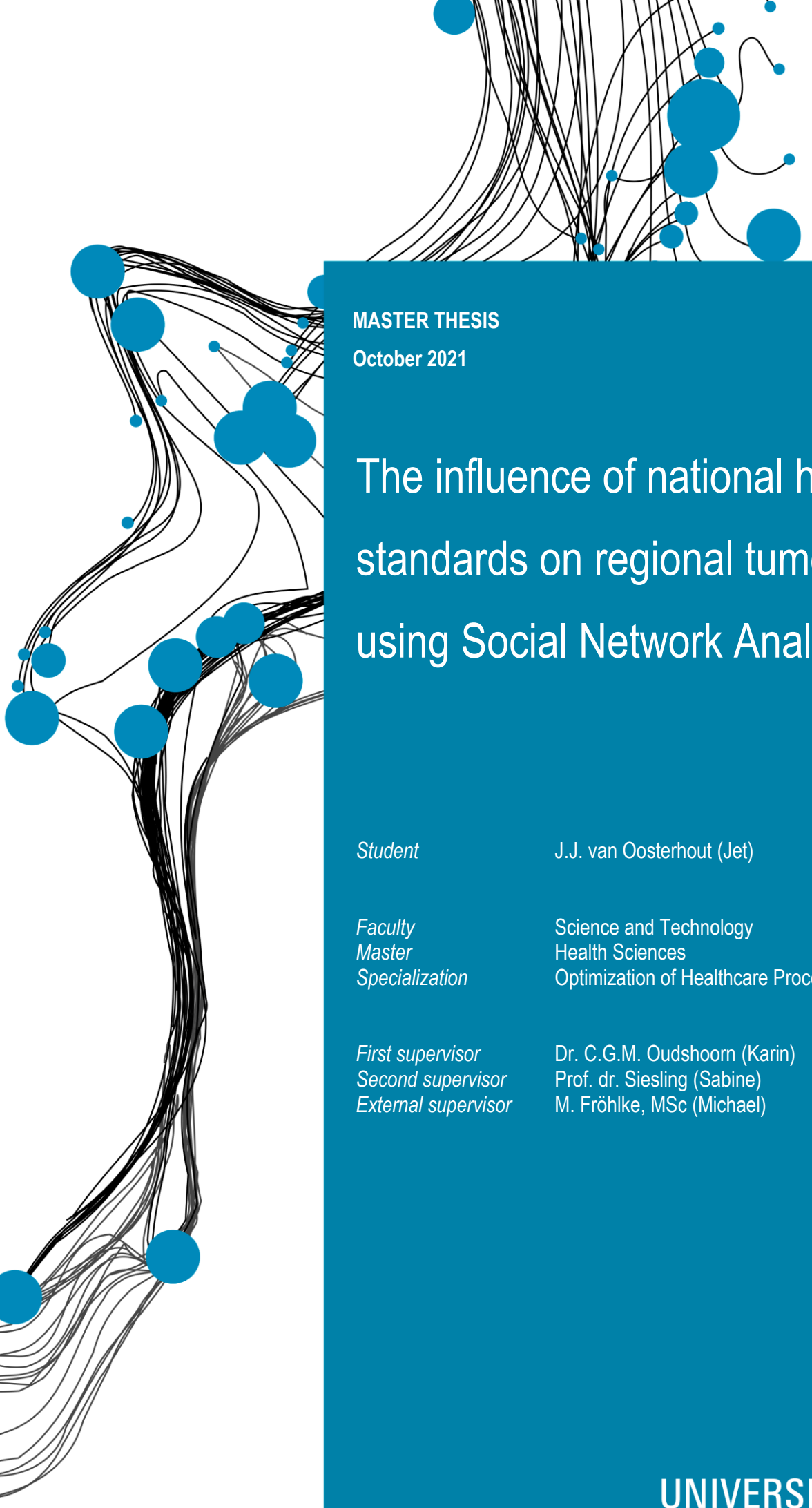

MASTER THESIS

October 2021

The influence of national hospital volume standards on regional tumor networks using Social Network Analysis

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Abstract

Purpose: National hospital volume standards are set to improve the quality of oncological care. The (changing) volume standards differ per tumor and treatment type. The purpose of this study is to analyze the development of tumor networks regarding hospitals within the region North East Netherlands in relation to the (changing) SONCOS volume standards over the period 2014 to 2019.

Methods: This study focuses on volume standards regarding prostatectomy, lung cancer care, and breast cancer surgery. Social network analysis is applied to visualize and quantify the developments of the networks of these treatments. The key network characteristic is the density, which describes the proportion of present connections from all possible connections between hospitals in the network. The trend in density is compared to the change in volume standards. Breast cancer surgery had no change in volume standard over the period under study and was taken as a comparator.

Results: For the three treatments, networks per year are visualized in sociograms. The number of hospitals inside the region North East Netherlands decreases from 19 in 2014 to 15 in 2019. A reduction in density of 52 %, 22 %, and 15 % for the year 2019 with respect to 2014 is observed for prostatectomy, lung cancer care, and breast cancer surgery respectively.

Conclusions: Network development was observed for tumor types with (prostatectomy and lung cancer care) and without (breast cancer surgery) changing SONCOS volume standards. Reasons for this development are hospital mergers and changing SONCOS volume standards (for prostatectomy and lung cancer care).

Introduction

In March 2009, the Dutch Healthcare Inspectorate (DHI) reported the need for oncological care to improve (Inspectie voor de gezondheidszorg, 2009). The report described an investigation of the DHI into the quality of care regarding patients with breast tumors, prostate tumors, lung tumors, and patients receiving palliative care. Large differences in quality of care were found within and between hospitals. The DHI imposed all hospitals to write an approach to improve their quality of oncological care and asked umbrella organizations to formulate guidelines for quality of care. This incited the Dutch Associations of Surgical Oncology (NVCO), Radiotherapy and Oncology (NVRO), and Medical Oncology (NVMO) to found together an oncological collaboration foundation, named the 'Stichting Oncologische Samenwerking' (SONCOS). Since 2012, SONCOS annually publishes a report, which describes qualitative and quantitative standards for oncological hospital care in the Netherlands. These standards should continuously encourage hospitals to improve the quality of oncological care (SONCOS, 2019).

Hospital volume is one of the quantitative standards in the SONCOS reports and describes per tumor and treatment type the total number of treatments a hospital should perform in a given period, mostly one year. Treatments can be specific treatments such as a specific type of surgery or adjuvant therapy but can also be more general such as the total number of patients treated. Extensive literature supports the relation between the quality of care and the hospital and surgeon volume for complex surgical procedures (Birkmeyer et al., 2002; Wouters et al., 2009). However, also for low-risk surgeries and nonsurgical cancers a positive volume-outcome relationship has been found in literature studies (Hillner et al., 2000). At present, hospital volume is a widely acknowledged indicator to measure the quality of care.

After publication of the yearly SONCOS report each February, hospitals should have implemented the standards within one year. In collaboration with 'Zorgverzekeraars Nederland', the umbrella organization of ten health

insurers in the Netherlands, SONCOS checks annually to what extent a hospital meets the standards. Via the so-called 'transparency portal', hospitals have the possibility to fill in a questionnaire that indicates if a hospital meets the SONCOS standards. If a hospital does not meet a standard, the hospital is asked to list their intended actions to still meet the standard in the comments of the 'transparency portal'. In general, it is not possible for all hospitals to meet the volume standards for all tumor types and treatments. In case the hospital deviates too much from the standard the hospital should consider retaining care for this specific cancer type or outsourcing oncological care components by collaboration with other hospitals and define agreements on referrals for these care components.

There are different issues to consider when making agreements between hospitals and other healthcare facilities about outsourcing care. First, from the patient's perspective, it is valuable to offer the care within the region and limit travel time. For example, a patient can be diagnosed in a small regional hospital located near to the patient's residence. Then, for surgery a patient can be referred to a specialized hospital which means more travel time. After surgery, the patient is again referred to the hospital of diagnoses for adjuvant therapy. This way the total travel time of a patient's treatment process is limited.

Second, hospitals should consider the financial consequences of the agreements they make. Outsourcing all oncological care of one tumor type means losing all patients of that tumor type and the corresponding income. Therefore, the outsourcing of components might be financially interesting.

Third, by outsourcing tumor specific care components, the knowledge within the multidisciplinary team of the referring hospital might decrease. Specialists might lose parts of their tasks, and this can cause a reduction in experience and job satisfaction. This might be solved by, for example, making an agreement that the specialists of the referring hospital can operate in the hospital that is referred to.

The issues from the three different perspectives can be seen as obstacles for hospitals to make agreements. Therefore, extrinsic motivation like SONCOS volume standards could incite to actually start collaborations between hospitals.

Over the years, hospital volume standards described in the SONCOS reports have changed for specific tumor types. As an example, until 2017 a hospital was allowed to perform radical prostatectomy if at least 20 of these treatments were performed per year (SONCOS, 2017). In 2018 and 2019 this volume increased to a standard of 50 and 100 treatments a year, respectively (SONCOS, 2018, 2019). Increasing volume standards often results in concentration of care and network formation (Middelveldt et al., 2018). It remains unclear how hospital volumes have changed over the years due to the SONCOS standards and how this affected the development of tumor networks. This research aims to study the development of tumor networks regarding hospitals within the region North East Netherlands in relation to the (changing) SONCOS volume standards in the period 2014 to 2019.

Theoretical Background

Network theory is the study of graphs that represent attributes and the relations between attributes. A network that represents people or groups of people as attributes and some pattern of contacts or interactions between them as relations is called a social network (Newman, 2003). When searching for existing literature, a lot of social network analysis in the field of medicine has been found focusing on for example the spread of infection diseases (Donker et al., 2010; Gandhi et al., 2012; Gardy et al., 2011; Rankin & Matthews, 2020), the influence of friendships on smoking behavior (Ennett et al., 2008; Mercken et al., 2012; Pearson & Michell, 2000), and interaction patterns within and between care facilities (Creswick & Westbrook, 2010; Cunha et al., 2016; Scott et al., 2005).

Social network analysis starts with visualizing the network in a graph, a sociogram. In a sociogram, the attributes of the network are represented by nodes and the relations between attributes are represented by edges. There exist directed graphs, where the edges point in a direction, and undirected graphs, where the edges are just lines. Directed graphs can be subdivided into cyclic and acyclic. A cyclic graph contains closed loops of edges, an acyclic graph does not. Figure 1 shows an example of a small network visualized in a directed cyclic sociogram.

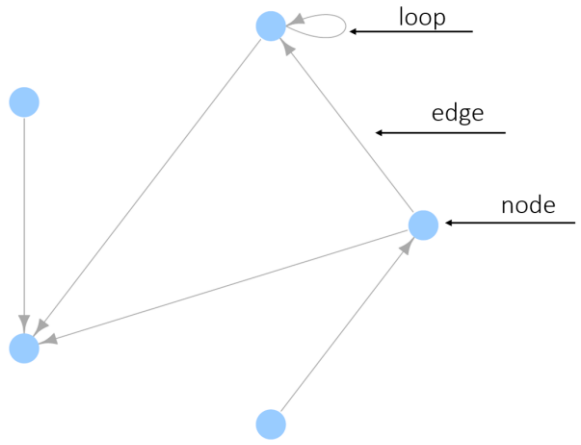

Fig. 1. An example of a small network.

A directed cyclic sociogram containing five nodes and six edges from which one closed loop edge.

After visualizing the network in a sociogram, network characteristics can be analyzed. Relevant characteristics concerning this research are node degree and network density. The node degree describes the number of edges connected to a node. In a directed graph, distinction is made between in-degree, out-degree, and total degree. In- and out-degree are the numbers of incoming and outgoing edges respectively, and total degree is the sum of incoming and outgoing edges. The density of a network is the ratio of all present edges with respect to all possible edges in the network (Scott, 2000). Therefore, the density is between 0 and 1 and can also be given as a percentage. The density is 1 or 100 % if each node is connected directly to every other node in the network.

Method

Data source

The data used for this research is obtained from the Netherlands Cancer Registry (NCR). The dataset contains variables describing patients, tumors, and treatments of all Dutch cancer diagnosis. Moreover, it contains characteristics of the hospitals of diagnosis and treatment. For the scope of this study, a subset was created containing all patients diagnosed in a hospital located in the region North East Netherlands between January 1st, 2014, and December 31st, 2019 (n = 152,096). 24 Hospitals are geographically located inside North East Netherlands of which a few have merged or have disappeared over the years. A mix of academic, training, and general hospitals are represented inside the region.

Selection of tumor treatment types

Table 1 gives the total number of cancer cases in North East Netherlands from 2014 to 2019 per tumor type for the tumor types with revised SONCOS volume standards (SONCOS, 2014, 2015, 2016, 2017, 2018, 2019). From this list, prostate cancer and lung cancer were selected because of their high total number of patients available in the dataset. In addition, breast cancer is selected for analysis as a comparator with no change in volume standards and an available dataset of similar size. In preparation for the analysis of the selected tumor types, different subsets of

patient groups of the tumor treatment types in the NCR data were made. A short explanation about usual treatment, the volume standard, and details about the subsets are discussed below per tumor type.

Table 1
Total number of patients per tumor type in North East Netherlands from 2014 to 2019.

Tumor type	Total (n)
Lung	14,669
Prostate	13,922
Bladder	7,683
Head and neck	3,857
Pancreas	2,995
Ovary and fallopian tube	2,054
Testicle	903
Liver	858
Thyroid	799
Soft tissue sarcomas	690
Penis	246
Eye melanoma	102
Adrenal gland and other endocrine organs	26
Sarcoma of male genitals and urinary tract	22

Prostatectomy

Prostate cancer or prostate carcinoma is the most common cancer in men. Every year about 12,000 men are diagnosed with prostate carcinoma in the Netherlands. The treatment of prostate carcinoma can consist of surgery, radiotherapy, chemotherapy, or a combination of these three and depends on the stage of the disease. The SONCOS volume standard concerns surgery, radical prostatectomy, which is often robotic assisted surgery. The volume standard for radical prostatectomy changed multiple times over the years from 20 (in 2014) to 50 (in 2018) to 100 (in 2019). In the period 2014 until 2019 in the region North East Netherlands, 13,922 cancer cases labeled as 'prostate' occurred (see Table 1). For analysis, a subset was made including all prostate cancer patients that received surgery specified as *prostatectomy* or *prostatectomy according Millin/Hryntschack prostatectomy* (n = 2808) and excluding patients referred to a hospital abroad (n = 171). A subset of 2637 patients was left for further analysis.

Lung cancer care

Yearly about 14,000 people in the Netherlands are diagnosed with lung cancer. Depending on the stage of the disease a treatment plan is made. The most common treatment options are surgery, radiotherapy, chemotherapy, immunotherapy, and targeted therapy. The SONCOS volume standard for lung cancer describes the number of new patients treated and has increased from 25 in 2014 until 2016, to 50 in 2017 until 2019. The available data of lung cancer care is 14,669 observations or patients (see Table 1). For the subset for further analyses, patients who did not receive treatment after diagnosis (n = 3698) were excluded. Also, duplicates (n = 246) were excluded because the SONCOS volume standard explicitly concerns new patients. After exclusion, a subset of 10,725 patients was left for analysis.

Breast cancer surgery

Breast cancer is the most common cancer in woman in the Netherlands. About 13,000 people are diagnosed with breast cancer per year. Treatment of breast cancer usually includes surgery, for which a SONCOS volume standard is described. Contrary to prostatectomy and lung cancer care, for breast cancer surgery, the SONCOS volume standard remains equal over the years (n = 50). In the NCR data, a set of 20,789 breast cancer patients diagnosed between 2014 and 2019 is available. The SONCOS standard of 50 surgeries per year concerns all types of breast cancer surgery. For this study, a subset was made including patients that received surgery specified as *ablatio (without OKD), amputation (with OKD),* or *lumpectomy (with* and *without OKD)* because these four types of surgery cover above 99 % of all types of surgeries. Patients diagnosed multiple times over the years were also included

multiple times (n = 458) and patients referred to a hospital abroad were excluded (n = 4). A subset of 15,926 patients was left for analysis.

Social Network Analysis

Social network analysis was used to investigate the influence of national hospital volume standards on the development of regional tumor networks. The regional networks of the selected tumor types are visualized in directed cyclic sociograms where the nodes represent hospitals, and the edges represent patient referral patterns. For all three tumor types, referrals are defined as a transfer of a patient from the *hospital of diagnosis* to the *hospital of most important treatment*. The *hospital of most important treatment* is a variable in the dataset and is defined by the NCR. In this research the subsets of the tumor types are selected so that they correspond to the SONCOS volume standards of these treatments.

After visualizing the networks in sociograms, the network characteristics node degree and density can be derived. In this study, the node degree concerns the in-degree, which is the number of incoming edges per node, including the loops. A high in-degree means a hospital receives patients from many other hospitals. This implies that these hospitals are central players in the network. A low in-degree is attributed to hospitals receiving less patients or in extreme cases only refer patients to other hospitals. In the sociogram, the in-degree can be visualized by the size of the nodes.

In this study, networks are expected not to be very dense because a hospital is only connected to a subset of the other hospitals in the network. When a network has a low density, this can be interpreted as a clear referral pattern, possibly caused by agreements or collaborations between hospitals in the network. Whereas a higher network density corresponds to a more random referral pattern.

Results

The sociograms of the networks of prostatectomy, lung cancer care, and breast cancer surgery are represented in Figure 2, 3, and 4, respectively. All three figures consist of six sociograms of the tumor networks of the years 2014 to 2019. Each sociogram is titled with the year of the network followed by the SONCOS volume standards of the corresponding year between brackets. The nodes (circles) in the sociograms represent the hospitals, and the edges (arrows) represent the referrals between the hospitals. The color of the node shows if the hospital is geographically located inside the region North East Netherlands (blue colored nodes) or outside the region (grey colored nodes). The nodes are also labeled with letters to be able to follow the development of a specific hospital over the years. Uppercase letters represent hospitals located inside the region and double lowercase letters represent hospitals located outside the region. The size of the nodes is determined by the in-degree which is the number of incoming edges. So, a large node is connected to more hospitals than a small node. Isolated nodes, i.e. hospitals that do not diagnose or refer patients, are excluded in the sociograms. The edges in the networks differ in thickness and represent the number of patients that are referred. Thicker edges correspond to more referrals. The arrows of the edges point in the direction a patient is referred. Some arrows are loops, these show the number of patients that a hospital treats itself. In the next sections, network characteristics per tumor type are discussed.

Prostatectomy network

Between 2014 and 2019, 2637 prostatectomies were performed by the network of the region North East Netherlands. In Figure 2, sociograms per year are presented and corresponding volume standards, between brackets, are shown. Table 2 gives characteristics of the sociograms per year. The total number of nodes or hospitals in the networks decreases over the years from 29 nodes in 2014 to 20 in 2019. For both the hospitals located inside and outside the region a decrease of nodes is observed.

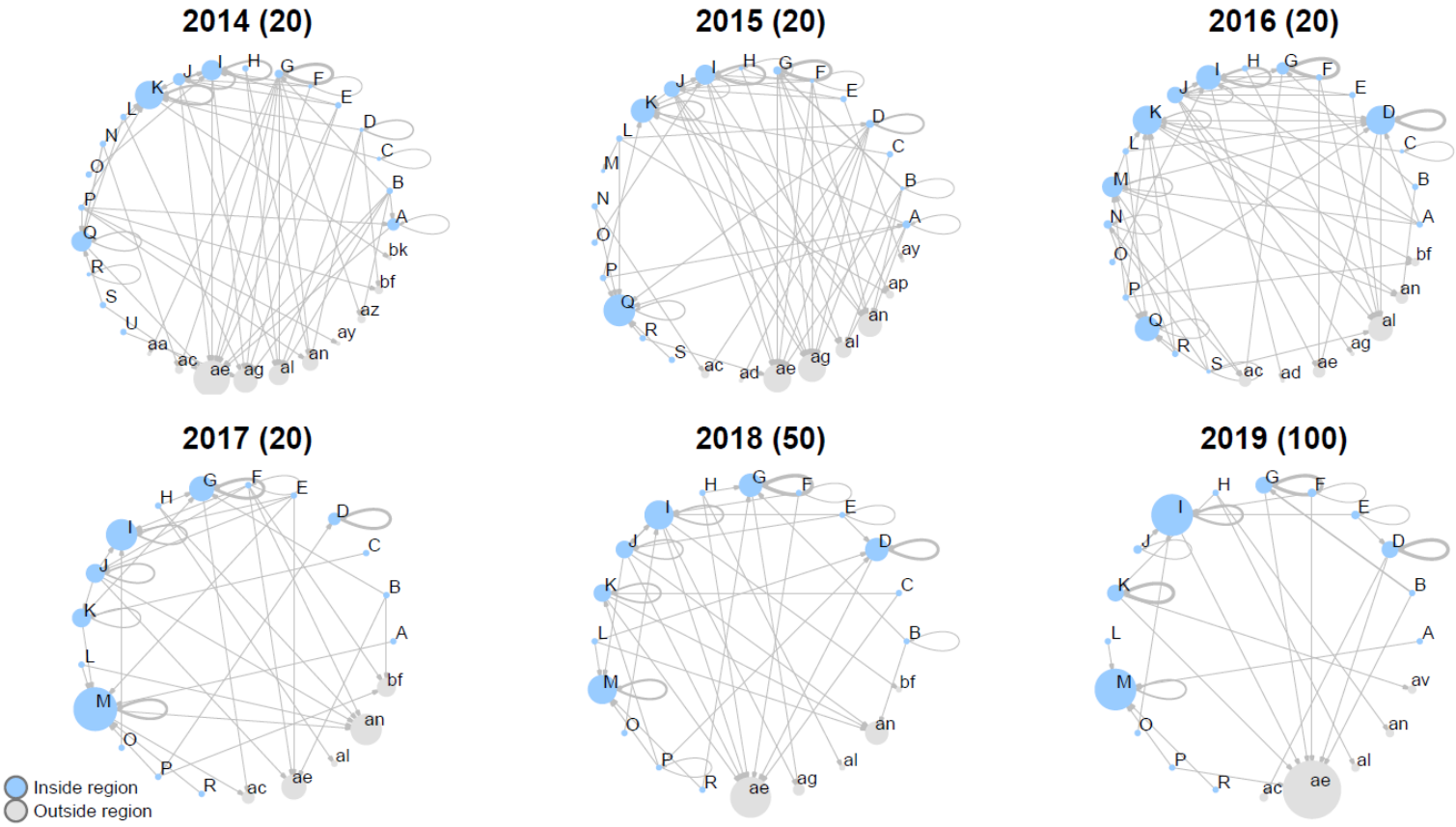

Fig. 2. Sociograms of the prostatectomy network of the region North East Netherlands from 2014 to 2019.

The year is followed by the SONCOS volume standard between brackets. The nodes represent hospitals, and the edges represent referrals between hospitals. The nodes are labeled and colored to show if the hospital is geographically located inside (blue nodes with uppercase letters) or outside (grey nodes with double lowercase letters) the region. The side of the nodes is determined by the in-degree (larger nodes mean higher in-degree). The edges differ in width and show the number of patients referred (wider edges mean more referrals). The arrows of the edges point in the direction a patient is referred. Loops are included and show the number of patients that a hospital treats itself.

In 2018, the prostatectomy network consists of 20 hospitals from which 15 are located inside and 5 are located outside the region. 10 Hospitals inside the region performed prostatectomy of which 40 % meet the SONCOS volume standard of performing 50 prostatectomies per hospital per year. In 2019, the total number of hospitals in the network and the regional division of hospitals in the network is equal to the situation in 2018. Regarding the hospitals inside the region, 8 performed prostatectomy and 1 (13 %) meets the volume standard of performing 100 prostatectomies per hospital per year. One hospital almost meets the volume standard and performed 92 prostatectomies in 2019. The density of the prostatectomy network decreases over the years from 0,75 % in 2015 to 0,36 % in 2019.

Table 2 Characteristics prostatectomy network.
The calculations of the (percentage of) hospitals that meet the standard are based on the number of treatments of patients diagnosed in a hospital located inside the region North East Netherlands.

Year	Number of nodes or hospitals					Perform surgery and meet the standard (%)	Volume standard (n)	Density (%)
	Total in the network (n)	*Located outside the region (n)*	*Located inside the region (n)*	*Inside the region and perform surgery (n)*	*Perform surgery and meet the standard (n)*			
2014	29	10	19	10	6	60 %	20	0.74 %
2015	27	8	19	11	6	55 %	20	0.75 %
2016	26	7	19	10	7	70 %	20	0.73 %
2017	21	5	16	7	6	86 %	20	0.48 %
2018	20	5	15	10	4	40 %	50	0.51 %
2019	20	5	15	8	1	13 %	100	0.36 %

Lung cancer care network

Regarding lung cancer care, 10,725 new patients were treated between 2014 and 2019 by the network of the region North East Netherlands. The sociograms per year and the corresponding volume standards, between brackets, are presented in Figure 3. Table 3 presents the network characteristics of lung cancer care. The total number of nodes or hospitals in the networks increased from 28 in 2014 to 30 in 2016 and then decreased to 23 in 2019. The number of hospitals located outside the region follows this trend. However, the number of hospitals located inside the region fluctuates the first three years and then decreases from 19 in 2016 to 15 in 2019.

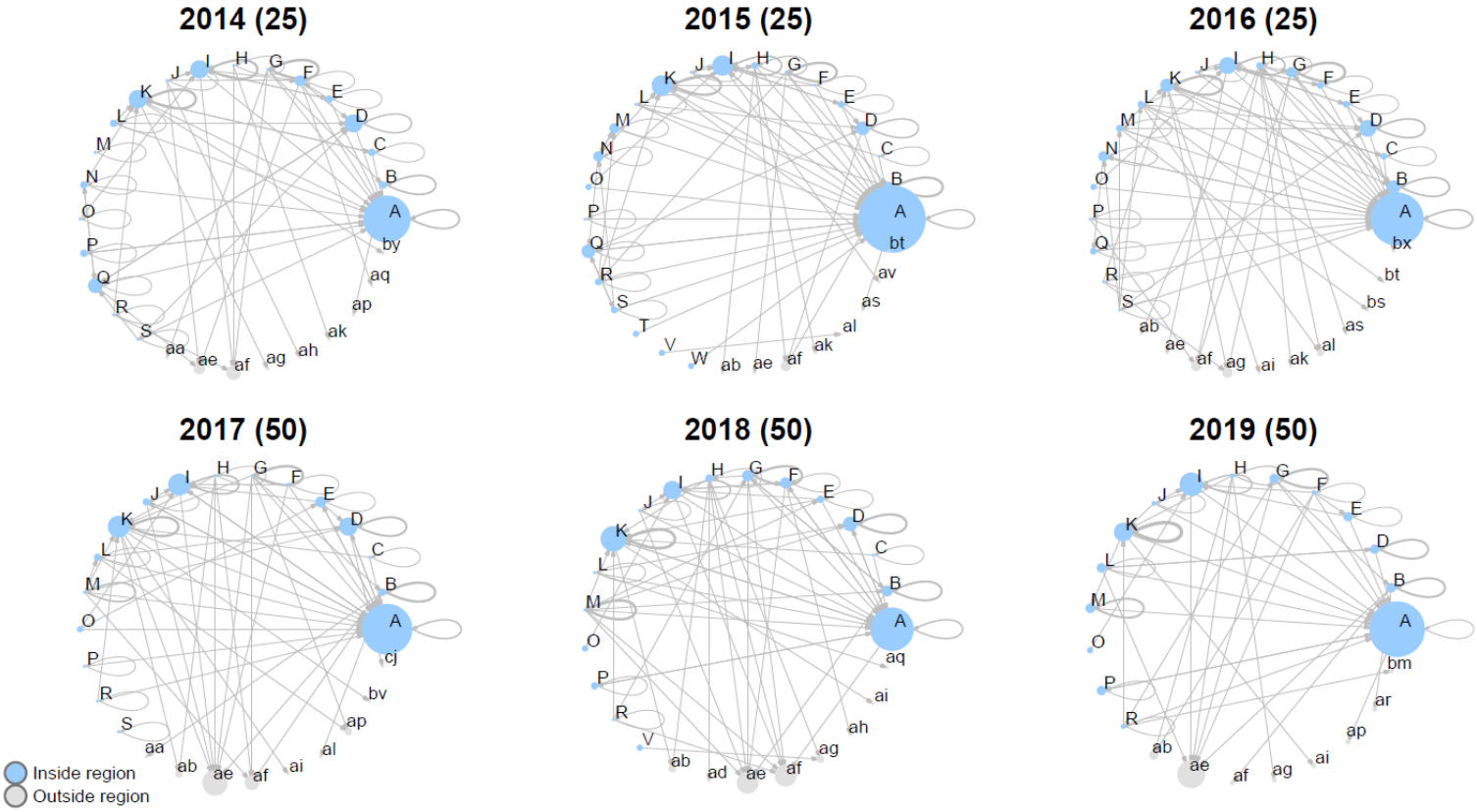

Fig. 3. Sociograms of the lung cancer care network of the region North East Netherlands from 2014 to 2019.

The year is followed by the SONCOS volume standard between brackets. The nodes represent hospitals, and the edges represent referrals between hospitals. The nodes are labeled and colored to show if the hospital is geographically located inside (blue nodes with uppercase letters) or outside (grey nodes with double lowercase letters) the region. The side of the nodes is determined by the in-degree (larger nodes mean higher in-degree). The edges differ in width and show the number of patients referred (wider edges mean more referrals). The arrows of the edges point in the direction a patient is referred. Loops are included and show the number of patients that a hospital treats itself.

In 2017, the SONCOS volume standard is increased from 25 to 50. The volume is described as the number of new patients treated per year. In 2017, 16 hospitals inside the region treat lung cancer patients, of which 75 % meet the volume standard of 50 patients per year. In 2018, 15 hospitals inside the region treat lung cancer patients, of which 73 % meet the volume standard of 50. In both years, above 50 % of the hospitals that meet the volume standard, meet the standard twice. In 2019, 14 hospitals inside the region treat lung cancer patients, of which 12 (86 %) meet the volume standard and 1 almost meets the standard by treating 49 lung cancer patients. In the first three years, the density of the network increased from 0,81 % in 2014 to 0,88 % in 2016. Then, in 2017, the density decreased. In 2018, again a little increase is observed whereafter the density decreases to the lowest percentage of 0,63 % in 2019.

Table 3 Characteristics lung cancer care network.
The calculations of the (percentage of) hospitals that meet the standard are based on the number of treatments of patients diagnosed in a hospital located inside the region North East Netherlands.

Year	Number of nodes or hospitals					Treat new patients and meet the standard (%)	Volume standard (n)	Density (%)
	Total in the network (n)	*Located outside the region (n)*	*Located inside the region (n)*	*Inside the region and treat new patients (n)*	*Treat new patients and meet the standard (n)*			
2014	28	9	19	19	17	89 %	25	0.81 %
2015	30	8	22	18	17	94 %	25	0.87 %
2016	30	11	19	18	17	94 %	25	0.88 %
2017	26	9	17	16	12	75 %	50	0.81 %
2018	25	8	17	15	11	73 %	50	0.81 %
2019	23	8	15	14	12	86 %	50	0.63 %

Breast cancer surgery network

Between 2014 and 2019, 15,926 breast cancer surgeries were performed by the network of the region North East Netherlands. In Figure 4, sociograms of the breast cancer surgery network are presented per year. Table 4 gives the network characteristics per year. The total number of nodes or hospitals in the network fluctuates over the years with a minimum of 20 in 2015 and a maximum of 30 in 2016. The number of hospitals located inside the region decreases gradually from 19 in 2014 to 15 in 2019. However, the number of hospitals located outside the region fluctuates between 2 (2015) and 11 (2016).

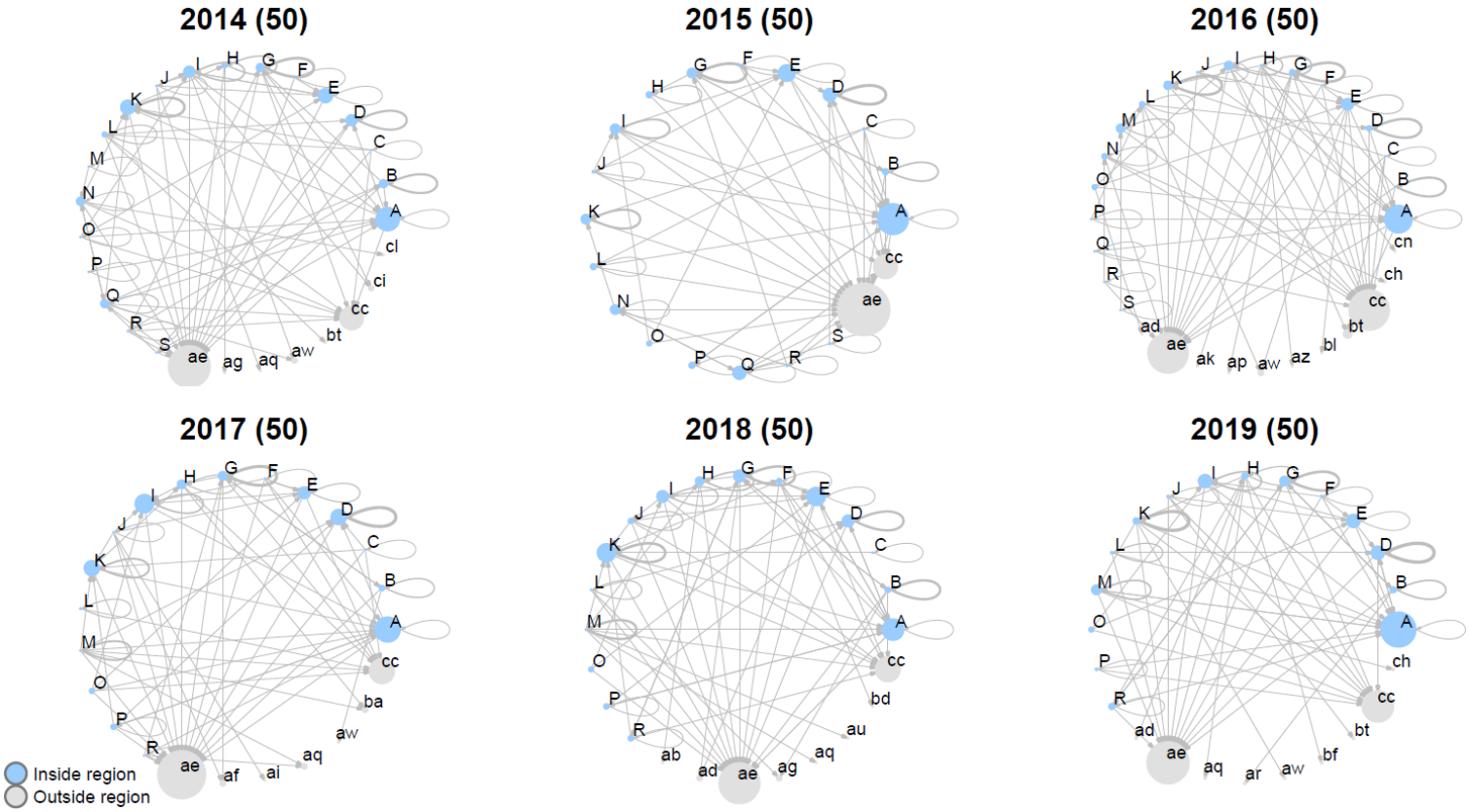

Fig. 4. Sociograms of the breast cancer surgery network of the region North East Netherlands from 2014 to 2019.

The year is followed by the SONCOS volume standard between brackets. The nodes represent hospitals, and the edges represent referrals between hospitals. The nodes are labeled and colored to show if the hospital is geographically located inside (blue nodes with uppercase letters) or outside (grey nodes with double lowercase letters) the region. The side of the nodes is determined by the in-degree (larger nodes mean higher in-degree). The edges differ in width and show the number of patients referred (wider edges mean more referrals). The arrows of the edges point in the direction a patient is referred. Loops are included and show the number of patients that a hospital treats itself.

The SONCOS volume standard is 50 for all years, which means that a hospital should at least perform 50 breast cancer surgeries per year. For all years the percentage of hospitals that perform surgery and meet the standard is above 80 % and twice a percentage of 100 % is achieved. Over the years, the density of the breast cancer surgery network fluctuates between 0.96 % (2014) and 0.81 % (2019).

Table 4 Characteristics breast cancer surgery network.
The calculations of the (percentage of) hospitals that meet the standard are based on the number of treatments of patients diagnosed in a hospital located inside the region North East Netherlands.

Year	Number of nodes or hospitals					Perform surgery and meet the standard (%)	Volume standard (n)	Density (%)
	Total in the network (n)	*Located outside the region (n)*	*Located inside the region (n)*	*Inside the region and perform surgery (n)*	*Perform surgery and meet the standard (n)*			
2014	27	8	19	19	16	84 %	50	0.96 %
2015	20	2	18	17	16	94 %	50	0.82 %
2016	30	11	19	18	16	89 %	50	0.92 %
2017	23	7	16	15	15	100 %	50	0.90 %
2018	24	8	16	15	14	93 %	50	0.91 %
2019	24	9	15	14	14	100 %	50	0.81 %

Discussion

The results of this study show that the networks of prostatectomy, lung cancer care, and breast cancer surgery develop over time. For all three tumor networks, the number of nodes or hospitals geographically located inside the region North East Netherlands decreases from 19 in 2014 to 15 in 2019. The change in the number of hospitals located outside the region differs per tumor type. Regarding prostatectomy, the number of hospitals located outside the region decreases from 10 in 2014 to 5 in 2019. For lung cancer care and breast cancer surgery, the number of hospitals located outside the region fluctuates over the years. Besides the change in the number of nodes in the networks, the density of the networks also developed over the same period. A reduction of 52 %, 22 %, and 15 % for the year 2019 with respect to 2014 is observed for prostatectomy, lung cancer care, and breast cancer surgery respectively. So, the proportion of present edges from all possible edges or connections in the network decreases.

The decrease in the number of hospitals located inside the networks can be explained by two hospital mergers. In both cases, multiple hospitals merged into one hospital with multiple locations. One of the factors playing a role in the decision to merge might be the changing SONCOS volume standards. The changes in the number of hospitals located outside the networks can also be caused by hospital mergers outside the region or could imply that hospitals inside the region made more clear agreements with specific hospitals outside the region.

The decrease in density can be caused by the development of patient referral patterns, which can be caused by two possible factors. First, it is possible that hospitals made more clear agreements about which hospital delivers which care in the network. A reason for more collaboration and agreements between hospitals is the changing SONCOS volume standards. Second, it is possible that the referral occurs before a patient enters the hospital. A general practitioner can already refer a patient to a specialized hospital.

Regarding prostatectomy, it is uncertain if the change of the volume standard from 50 in 2018 to 100 in 2019 was an appropriate increase. Already in 2018, only 40 % of the hospitals met the standard of 50. In 2019, 13 % (n = 1) of the hospitals in the network met the volume standard of 100 and one hospital almost met the standard. This suggests that either the hospitals in the network are not able to meet this standard, or the hospitals in the network need more than one year to develop to meet the standard. Another reason for the low percentage of hospitals that meet the standards could be the type of surgery. Radical prostatectomy is often robotic assisted surgery for which a patient is referred to a specialized hospital at which a surgical robot is available. However, when in other stage of the disease, open surgery also occurs. This type of surgery is seen as low-complex and therefore can be performed by most urologists so no referral to a specialized hospital is needed. In the sociograms, the loops with low numbers can be open surgeries. The question emerges how low hospital volume of open surgery influences the quality of care. This issue should be discussed by the Dutch Association of Urologists (NVU).

Regarding lung cancer care, the percentage of hospitals that met the standard was 89 % in 2014 and 94 % in 2015 and 2016. In 2017 the SONCOS volume standard doubled to 50 whereafter 75 % and 73 % of the hospitals met the standard in 2017 and 2018, respectively. This decrease shows that for some hospitals it was not possible to adapt to the increased volume norm within one year. However, it is remarkable that in 2017 and 2018 above 50 % of the hospitals that met the volume standard, met the standard twice. In 2019, 86 % of the hospitals met the standard, which can be explained by a merger between two hospitals. As mentioned before, one of the reasons to merge might be the changing SONCOS volume standards.

Regarding breast cancer surgery, the SONCOS volume standard remains the same between 2014 and 2019 (n=50). However, the results show that the network changes over the years. In 2014, the number of hospitals located outside the region is remarkably low (n = 2). The year before and the years after, the number of hospitals located outside the region varies between 8 and 11. This could mean that in 2014 more patients were treated inside the network, so less referrals occurred. Or this could imply that in 2014 clear agreements were made between the network and two hospitals located outside the network. Besides this, the percentage of hospitals inside the region that meet the standard increases over the years. This could imply that in the first three years, the network was still adapting to the volume standard.

Other factors could also play a role in the development of a network. Patients can ask for referral for treatment in a specific hospital. The patient's preference can be influenced by issues such as travel time and experiences of former patients. Also, specialists can have preferences regarding referring patients to specific fellow specialists. Next to this, changes in the number of medical specialists and the composition of the team of medical specialists in a hospital can play a role in network development. For example, a transfer of a surgeon to another hospital in the network could affect referral patterns in the network. Furthermore, hospitals can change their policy which affects network development. Policy changes can be specialization in a type of cancer and outsourcing care components. Besides this, next to hospital volume standards, SONCOS also describes other quantitative and qualitative standards per tumor and treatment type. The standards that were not considered in this research could also play a role in network development.

This study shows that social network analysis can be a helpful tool to gain insight in the development of tumor networks. It can help supervising organizations like SONCOS to control whether hospitals meet the volume standards and what period hospitals need to adapt to revised standards. Also, this study can help executive organizations, i.e. the hospitals in the network, to understand the development of their network. The quantification and visualization of mergers, collaborations, and agreements can gain insight in how decisions effect the network development.

Future research can investigate other factors that explain the network development like patients' and specialists' preferences, and other quantitative and qualitative standards. Next to this, future research could extend this research by applying social network analysis on a larger dataset. For the scope of this study, the region North East Netherlands was selected. Applying social network analysis on a dataset of the entire country results in a more complete picture of the tumor networks in the Netherlands. This way, for all hospitals in the country, hospital volumes can be calculated and compared to SONCOS volume standards. Furthermore, this research could be extended by analyzing additional tumor types. For about 12 other tumor types the SONCOS volume standards have changed over the years. If all tumor networks of the Netherlands are analyzed using social network analysis, linking the network development to the SONCOS standards would be more accurate. Furthermore, analyzing the development of networks for which SONCOS standards remain the same seems also interesting for further investigation. This research made a start by analyzing the breast cancer surgery network. Of course, many other tumor and treatment types are available for social network analysis. Lastly, further research could investigate the group of hospitals that does not meet the SONCOS volume standards according to our results. The sociograms show multiple nodes with loops with a low number. Further investigation is needed to find the causes of low hospital volumes.

Limitations

This study has several limitations. First, the subsets per year are created based on the patients' date of diagnosis. It occurs that a patient diagnosed in December is treated in January next year. This patient is included in the subset

of the year of diagnoses, which is the year before the actual treatment. So, the sociogram of a network of a specific year can contain a few patients that have been treated the next year.

The second limitation concerns the definition of a referral in this study. A referral is defined as true when the hospital of diagnosis is not equal to the hospital where most important treatment takes place. However, the hospital of most important treatment is not necessarily the hospital where the first treatment takes place. Therefore, in theory, it is possible that a patient is referred for first treatment and thereafter again referred for most important treatment. Then, defining the referral as this research does is not accurate. However, in practice this does not occur often because in most patients are referred for most important treatment or adjuvant therapy after most important treatment.

The last limitation is that this study only includes patients diagnosed in hospitals located inside the region North East Netherlands. So, when a patient is diagnosed in a hospital outside the region and referred to a hospital inside the region, this is not included in the hospital volumes in the results. However, it is expected that including referrals into the region will not result in major changes of the hospital volumes of North East Netherlands.

Conclusion

This research investigated the development of the networks of prostatectomy, lung cancer care, and breast cancer surgery within the region North East Netherlands over a six-year period in relation to the (changing) SONCOS volume standards. The results show a decrease in the number of nodes or hospitals geographically located inside the region and a decrease in density of the networks. The number of hospitals inside the region North East Netherlands decreases from 19 in 2014 to 15 in 2019. A reduction in density of 52 %, 22 %, and 15 % for the year 2019 with respect to 2014 is observed for prostatectomy, lung cancer care, and breast cancer surgery respectively. Thus, network development was observed for tumor types with (prostatectomy and lung cancer care) and without (breast cancer surgery) changing SONCOS volume standards. Reasons for this development are hospital mergers and changing SONCOS volume standards (for prostatectomy and lung cancer care). These findings show that social network analysis is an appropriate method to quantify and visualize the development of tumor networks and extend the knowledge of factors affecting tumor network development which can contribute to improvement of the formulation of national hospital standards.

Acknowledgements

The author thanks the registration team of the Netherlands Comprehensive Cancer Organization (IKNL) for the collection of data for the Netherlands Cancer Registry as well as IKNL staff for scientific advice.

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