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Social network analysis of illicit organ trading networks: The Medicus case

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Abstract
Organ trafficking has been receiving more attention in recent years as its association with transnational crime organizations became evident. Most of the academic studies available on this topic are qualitative case studies, descriptively analyzing the nature of the crime and the agents involved. These studies often highlight the unique nature of organ trafficking, which is the involvement of medical service providers in the network. There have been, however, no effort made to examine the connections between medical service providers and other agents in the network in a quantitative fashion. This study presents unique quantitative data extracted from the "Medicus case", a well-documented court case involving kidney trafficking that surfaced in Pristina, Kosovo, in 2008. Social Network Analysis (SNA) was employed to quantitatively analyze the structure and characteristics of the kidney trafficking network. The results reveal that there was a significant variation in the level of involvement in kidney trafficking both across and within different types of agents. Notably, medical staff, facilities, and brokers played vital roles in the kidney trafficking network. Moreover, kidney sellers held a more prominent role than kidney buyers, with certain sellers playing particularly influential roles. In sum, this study demonstrates the promise of SNA as a tool for understanding kidney trafficking networks, and that further research is warranted to fully explore its potential in this field.

Keywords Social Network Analysis · Organ Trade · Criminal Networks · Transplant Tourism · Organized Crime

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Introduction

Organ trafficking has become a significant security threat in recent years, especially since new evidence on Middle Eastern criminal organizations exploiting refugees who sell their organs (primarily kidneys) for their passage to Europe (Columb 2017b, 2017a; Fraser and Koizumi 2017; Sanchez 2015) was discovered. In response to the emerging threat, several transnational initiatives have been launched including World Health Assembly (WHA) in 2004 and the formation of the Declaration of Istanbul Custodian Group in 2008, which now operates as the principal international entity to control organ trafficking in coordination with health authorities, law enforcement agencies and media organizations (Danovitch et al. 2013).

From the researchers' perspective, one of the major issues in studying this global security issue is the lack of quantitative data that allows us to assess the extent of the problem as well as the structure of the criminal networks enabling illegal transplants. The current estimate indicates that 5–10% of all organ transplants were performed illegally (Lancet 2007). While the accuracy of this estimation has been debated (Columb 2015), it has been widely cited and used to convey that the problem is of global significance (Jafar 2009; Lancet 2007). Another knowledge gap exists on the structure of organ trade networks. According to Ambagtsheer et al. (2014), the agents involved in the network and their roles are some of the most frequently debated topics in the studies on organ trade, along with other topics such as the causes of its practice, the ethics of organ sales, the supply and demand of available organs/kidneys and the efficacy of current legislation. Gathering such information is challenging due to the hidden nature of criminal networks (Manzano et al. 2014).

Given the background, the current paper aims to shed light on the structure of kidney trade networks by applying Social Network Analysis (SNA) to the "Medicus case", a well-documented case with the network structure that seemingly resembles many other organ trade cases found elsewhere. While SNA has been applied to examine various illicit networks, no rigorous application to illicit organ trading networks have been attempted thus far. A preliminary effort that applied SNA to understand the agent network of the Medicus case (Albarán et al. 2017) was conducted as a preparation for a TV show known as The Traffickers. We extended their preliminary work by extracting more detailed and accurate information available from the court material (Pristina 2013) and by performing additional SNA analyses to generate relevant statistics. The main purpose of the current study is to test the usefulness of this quantitative visualization tool in understanding and analyzing the structure of illicit organ trade networks. The study contributes to existing debates regarding the organization and the structure of criminal networks, at both local and transnational levels. The following section provides a literature review on criminal networks and a brief description of the occurrences surrounding the Medicus Case is provided. Sections 3 and 4 present the methodology and the results respectively. Finally, we present the discussion of the results and future work to be done in Sect. 5. Section 6 concludes the paper.

Criminal networks and the medicus case

Traditions of social network studies

Social networks are composed of nodes and edges, where nodes represent various actors such as individuals, organizations, or countries, and edges signify the connections between pairs of actors. These actors possess distinct attributes, for example, an individual's gender or age, the nature of an organization (e.g., Sicilian Mafia vs. Yakuza), or a country's level of law enforcement. On the other hand, these edges reflect diverse forms, such as communication or friendship among individuals, cooperation or transactions between organizations, or trade agreements or human trafficking between nations (Li 2021; Matusitz 2013; Newman 2010, p. 110; Wasserman and Faust 1994, p. 29).

Studies of social networks can be categorized into three traditions: ontology and epistemology, model-based studies, and institutional or cultural studies (Pachucki 2018). First, ontology and epistemology are philosophical concepts that respectively explore the nature of existence and reality, and the creation and dissemination of knowledge. In the context of social network theory, ontology examines the fundamental components of social networks, such as nodes and edges, as well as the properties and relationships between these components (Vicsek et al. 2016). Epistemology, on the other hand, investigates how knowledge about social networks is generated and validated through theoretical frameworks, observations, and analytical techniques (Singh 2019). Second, model-based studies of social networks focus on understanding the patterns of connections between nodes and how these patterns can be used to explain social phenomena. These studies typically employ mathematical models to represent networks and examine the role of antecedent or consequential network variables in explaining social phenomena (Borgatti and Halgin 2011; Borgatti and Foster 2003). The third approach, institutional or cultural studies, emphasizes the contextual variation in the meanings of social networks. This approach views social networks as a way of understanding how institutions, culture, and geography shape social interactions (Fuhse 2018; Fuhse and Gondal 2022; McLean 2016). From an analytical perspective, however, the last two approaches are not substantially different. The cultural or institutional components can be operationalized as network measures or modeled as different units of analysis. The current study employs the model-based approach, of which applications on criminal networks are briefly reviewed in the following section.

Model-based criminal network research

The study of model-based criminal networks can be broadly categorized into three approaches (Borgatti and Foster 2003). The first approach focuses on exploring how network structures influence the behaviors or outcomes of a node. In the context of criminal research, this explanatory approach examines how the structure of criminal networks affects the control of information or resources, the spread of criminal behavior, or the development of criminal subcultures. For example, various factors such as the strength of ties, network density, and network centrality among individuals within gang networks significantly contribute to the diffusion of violence (Papachristos et al. 2013). Also, Calderoni (2015) discovered that weighted degree centrality and betweenness centrality are often correlated with individuals holding leadership positions in a criminal organization.

The second approach aims to analyze the attributes of nodes in order to predict and understand variations in network variables. Researchers in this approach explore how attributes such as age, sex, criminal history, and social status are associated with a node's position or role in the criminal network. For example, a study by McCuish et al. (2015) examined a homicide co-offending network and found that offenders were frequently promoted to high-ranking positions in the network following the homicides. Similarly, Diviák et al. (2020) investigated a criminal network and discovered that women were less prevalent in the network and often occupied disadvantageous positions, frequently being connected through male intermediaries.

The third approach in social network theory focuses on how network variables are associated with each other. Researchers employing this approach commonly use the Exponential Random Graph Model (ERGM) or the Stochastic Actor-oriented Model (SAM) to account for interdependencies or connections between nodes within a network. For example, Bright et al. (2019) and Berlusconi (2022) applied the ERGMs to examine how dyadic effects, preferential attachment, and triadic closure contribute to the formation, maintenance, and dissolution of ties within criminal networks. In another study, Diviák et al. (2022) utilized SAM to explore how factors such as ethnic homophily, triadic closure, network popularity, pre-existing ties, and co-location are associated with the formation of terrorist networks operating in the Netherlands.

In this study on the kidney trade network, our analytical approach closely aligns with the first and second approaches. Our aim is to discern distinct roles of all those individuals who were involved in the kidney trade network, such as kidney sellers, buyers, medical personnel involved in surgeries, brokers, and other facilitators who enable illegal transplants (including hospitals, testing labs, and corrupt officials). The success of these transactions relies on specialized expertise and facilities, setting illicit organ/kidney trade networks apart from other types of dark networks. Particularly, the involvement of highly trained surgeons and complete medical teams, encompassing anesthesiologists and post-care nurses, is essential[1] (Ambagtsheer et al. 2014).

We proceed to investigate the interactions among these agents, identifying disparities in influence and pinpointing those occupying broker positions responsible for controlling information flow. Through the application of SNA, we leverage this method to portray complex human networks and relationships in an accessible

[1] Sensationalized news stories tell of people being kidnapped and left for dead on the road, but this narrative is not strongly supported by evidence. It is less risky for a transplant surgeon to perform an illegal surgery in such a way that does not put either kidney provider or recipient at risk, because it is less likely that complications will arise. See (Columb 2015) for more information.

manner. This involves visualizing these networks, quantifying interactions between agents, and uncovering the extent of influence wielded by these agents within the network.

The Medicus case

In 2007, the owner of the Medicus Clinic contacted a transplant surgeon and, over the course of many email exchanges, planned to perform illegal kidney transplants at the clinic with the help of other medical professionals. One of the kidney sellers was found at Pristina Airport, weak and pale after the operation, along with the brother of the kidney recipient, and two of the brokers. However, only the seller was detained, and the brokers avoided arrest. This led to an investigation that shut down the illicit operations at the clinic and the arrest of most of the personnel involved. However, some agents of the network initially avoided custody, many of whom had strong brokerage roles (Pristina 2013). A general sequence of the events is outlined next to provide context about the network operations.

Phase 1: Recruitment

Potential sellers would usually contact a broker by responding to a newspaper or internet advertisement. The broker(s) might meet with them in person or conduct all business electronically (by phone and email). The broker would discuss the payment amount and make all the arrangements for the seller to travel to Kosovo. They might arrange for a family member or friend to come along as well. Sellers would never receive money during this phase.

For potential buyers, the process was largely the same, except instead of responding to advertisements, they would usually contact one of the brokers directly through an existing connection. The brokers would meet with potential buyers in person more often than they did with the potential sellers, part of a "customer service" pattern that provided better treatment to buyers than sellers. Buyers usually paid most of the total cost during this phase.

Phase 2: Departure from home to arrival in Kosovo

All parties involved had to stop in Istanbul as a transient location where sellers and buyers had their blood drawn one last time either at the hotel or at the lab owned by one of the agents located there. At least 7 of the buyers were taken to the lab in Istanbul to meet the lead transplant surgeon who also owned the lab. In contrast, there were no witness accounts of kidney sellers being taken to the lab, instead of having their blood drawn at the hotel. The sellers and buyers, along with their family members, would then fly to Kosovo. Several of the accounts indicate that other people joined them in Istanbul for the flight to Kosovo, including brokers.

Table 1 Distribution of Seller and Buyer Nationality

Nationality	Seller	Buyer	Total
Belorussian	1		1
Canadian		1	1
German		1	1
Israeli	2	8	10
Kazakhstani	1		1
Moldovan	1		1
Polish		1	1
Russian	2		2
Turkish	4	1	5
Ukrainian	1	2	3
Grand Total	12	14	26

Phase 3: In Kosovo

Upon landing in Kosovo, all individuals were picked up at the airport and driven to the clinic for surgeries. Occasionally, some would be picked up via taxi, but the newcomers were usually picked up by someone from the clinic. Sellers and buyers were given documents to sign that "legitimized" the operation, and the transplant surgeries would take place. After the surgery, buyers would often stay at the clinic for several days, taking time to recover. Sellers, however, were given less post-operation care and were sent home earlier than their buyer counterparts.

Phase 4: Departure from Kosovo, return home

After the surgery and post-operation care, both buyers and sellers would be flown directly home. Some sellers received their payment after returning home while others were never paid. Some sellers would be approached at this stage and be offered the opportunity to recruit others. For some, this was an imposed condition for receiving their initially promised payment, something that was not originally made known to them. There is very little information about the buyers after they return home. Table 1 shows the number of sellers and buyers by their nationality. Israel provided a significant portion of the willing buyers compared to the other countries while Turkey provided a significant portion of willing sellers. This table only shows the nationality of the 26 individuals for whom the nationality information was available.

Methodology

Source material and data

The source material for our analysis (Pristina 2013) is a court record that summarized many of the key court proceedings that took place after the arrest of several

Table 2 Agent Categories

Agent	Description
1. Buyer	The person who received the transplanted kidney from the seller/seller
2. Seller	The person who provides the transplanted kidney to the recipient/buyer
3. Broker	Someone who created connections between buyers and sellers, organized transportation, and was responsible for the exchange of money
4. Transplant surgeon	Surgeons who participated in the transplant surgeries
5. Anesthesiologist	A member of the medical team who was responsible for anesthetic during the surgeries
6. Lab worker	Lab workers involved in lab testing
7. Sterilization Nurse	Nurses involved in surgeries
8. Clinic owner	Agent K36, the clinic owner
9. Ring Organizer	Agent K42, the agent who was allegedly responsible for recruiting and organizing the network (ring) of people who searched for potential donors
10. Director/Manager	Agent K4, son of the clinic owner K36, reported to be responsible for many of the behind-the-scenes operations of the clinic

agents involved in the Medicus case. It contains the judgements and charges made to the defendants, a list of the known transplant surgeries, and transcripts of several key witness statements. Most of the information regarding agent interactions was derived from the witness statements.

To convert the information from court records into usable data, the document was systematically examined. Each agent involved was identified and given a code to represent them.[2] Agents were then classified into 10 following groups depending on the role they played in the network (Table 2).

Likewise, a connection between two agents was established when we identified an interaction between the agents. Each interaction was identified with a direction (e.g., agent *i* contacted agent *j*), and the number of interactions was counted for each agent. All interactions between agents were then classified by the nature of interaction.[3] We identified 3 categories, i.e., surgical-related, brokering-related, and laundering-related interactions, each of which distinctively characterizes the nature of interaction. The "Surgical" category encompasses all interactions related to a surgical procedure. The "Brokering" category encompasses all interactions related to the process of connecting a seller and recipient, including the organization and execution of travel to and from Pristina. The "Laundering" category encompasses all interactions related to some effort that was made to legitimize the transplant or perpetuate the secrecy and stability of the network. Within each category, we classified each interaction using sub-categories used in the prior work done on the Medicus case (Albarán et al. 2017) except for the 3 categories (CONV, PLAN, and DOC)

[2] See Appendix. We note that the choice to codify names comes in part because victim names were included in the source material. Additionally, the names are not strictly necessary for the analysis. Our focus is largely an analysis of agent roles and responsibilities rather than individual names.

[3] See Appendix.

Table 3 Interaction Categories

Interaction category	Interaction sub-category	Definition
SURGICAL	1. ASTSUR	Assisting the lead surgeon in an illegal kidney transplant
	2. ANEST	Serving as an anesthesiologist in an illegal kidney transplant
	3. PFRM	Performing (or acting as the lead surgeon) in an illegal kidney transplant
	4. BAST	Being an assistant in an illegal kidney transplant
BROKERING	5. OFPMT	Offering a payment of money
	6. OFRCT	Offering someone the opportunity to become a recruiter of sellers
	7. PREP	Preparing someone for a transplant, including actions taken by brokers to organize a patient's travel, driving them to the clinic, or having lab work done
	8. REC	Recruiting someone to sell a kidney
LAUNDERING	9. VLNT	Violent – being threatening toward someone
	10. CONV	Conversation between agents was observed, but nature/content of conversation is unknown
	11. PLAN	Making plans to establish the Medicus clinic, or to conduct illegal kidney transplants
	12. DOC	Providing documentation to be signed that legitimizes the process (the patient signifies that they are an unpaid voluntary seller)

Table 4 Illustration of Coding for Agent and Interaction Specification

On 13 December 2007, [redacted] emailed [redacted] and wrote

Hi, As I promised I send you all the documents (original + English from the notary)… I hope to get the result soon. I would like to thank you one more time for everything. All my best. [redacted]. PS: I send you in 2 mails.

Source ID	Target ID	Interaction Sub-category	Interaction Category	Weight	Transplant date	Page of Interaction
K93	K36	PLAN	LAUND	1	2/15/2008	96

which we added for further specification. Table 3 provides a definition of each of the interaction categories and sub-categories.

Table 4 illustrates how we coded the agent and interaction information from the representative sentences found in the court material. The "Page of Interaction" column refers to the page of the court records where the interaction was identified, while "Weight" represents the number of interactions.

Based on all agents and interactions information extracted from the court material, a network $G = (N, E)$ was built where the set of agents is represented by the set N of nodes, and the set of interactions is represented by the set E of edges of the network. Any edge $(i, j) \in E$ represents an interaction between the two agents represented by the nodes i and j.

Edges can either be unidirectional (referred to as directed edges) or bidirectional (undirected edges). An example of a directed edge in social media, for example, is a tweet (account i sends/receives a message to/from account j) while an example of an undirected edge includes Facebook friends (persons i and j are mutually connected). A directed edge can reflect either indegree or outdegree interaction. An indegree interaction reflects an interaction initiated by a neighbor node j to the focal node i (e.g., account i received a message from account j), while an outdegree interaction reflects an interaction initiated by the focal node i to a neighbor node j (e.g., account i sent a message from account j). The edges in the current study are all directed edges. We used the open-source software *Gephi* to visualize the network and perform SNA using 3 centrality measures, which are described below.

Network statistics

The statistics produced as part of SNA allow for a quantitative analysis of networks. This study used three types of centrality scores, i.e., degree, betweenness and pagerank centrality scores, to understand the importance of the roles played by various agents involved in the Medicus network.

Centrality scores can be computed with a weight w_{ij} assigned to each edge *(i,j)* (weighted score) or without (unweighted score). Unweighted centrality scores measure the level of interactions between two nodes in a binary fashion (1 if there is any interaction, and 0 otherwise), while weighted centrality scores measure the level of interactions using the number of interactions between the two nodes. Our study focused on *weighted* centrality scores to capture the intensity of the interactions among nodes. Each type of centrality score is defined and detailed below.

Weighted and directed degree centrality

The degree centrality is computed for each node of the network. It measures the number of interactions that the node was involved. We calculated both outdegree and indegree scores for the degree centrality. For the weighted outdegree centrality, the score is the sum of a focal node's directed connection to the neighbor nodes; while for weighted indegree centrality, the score is the sum of neighbor nodes' directed connection to a focal node. The formula to compute the weighted outdegree centrality of a node i is the following (Newman 2004; Wasserman & Faust 1994):

$$D_i = \sum_{j \neq i \in V}^{n} w_{ij} x_{ij} \tag{1}$$

D_i is the outdegree centrality score of $i \in V$, n is the number of nodes in the network, w_{ij} is the weight associated with the directed edge (i, j) from $i \in V$ to $j \in V$, and x_{ij} is equal to 1 if the edge from i to j exists in the set E and it is equal to 0 otherwise. The outdegree centrality score can be modified as the indegree centrality score, where x_{ji} is equal to 1 if the edge from j to i exists in the set E and it is equal to 0 otherwise. w_{ji} is the weight associated with the directed edge from j to i (Barrat et al. 2004).

Weighted betweenness centrality

The betweenness centrality score is computed for each node of the network. It measures the number of times a node lies on the shortest path between two other nodes. This measure reflects which nodes could potentially operate as "bridges" between nodes in a network. It does this by identifying all the shortest connecting paths between any two nodes in the network and then counting how many times each node falls on one. The formula for calculating the directed weighted betweenness score B_i of a node i is defined as (Newman 2004; Wasserman & Faust 1994):

$$B_i = \sum\nolimits_{j \neq k \neq i \in V} \frac{\sigma_{jk}(i)}{\sigma_{jk}} \tag{2}$$

where $\sigma_{jk}(i)$ is the sum the weights of all the shortest paths from j to k passing throught node i; while σ_{jk} is the sum of the weights of the all the weighted shortest paths from j to k. Thus, the betweenness score denotes the percentage of weighted shortest paths in the network which pass through i(Barrat et al. 2004).

Weighted and directed pagerank centrality

The pagerank centrality is computed for each node in the network. It reflects the importance of the neighbor nodes that a node is connected to. More specifically, node i has a

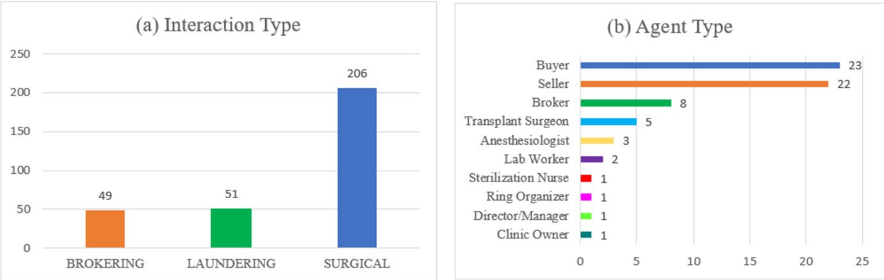


Fig. 1 Types of Interactions and Agents in the Medicus Network

higher pagerank centrality if it is connected to the nodes with a higher weighted indegree or outdegree centrality value. Thus, a node is likely to have a high PageRank centrality score even with a few connections if it is connected to highly weighted indegree or outdegree nodes compared to those nodes that are well connected to the nodes with a low weighted centrality value. For pagerank centrality, we calculated both outdegree and indegree scores. The formula for the weighted pagerank outdegree centrality $PR_i^{(out)}$ of node i is recursively calculated as (Zhang et al. 2021):

$$PR_i^{(out)} = \gamma \sum_{i \neq j \in V} \frac{w_{ji} x_{ji}}{D_j^{(out)}} PR_j^{(out)} + \frac{1-\gamma}{n} \tag{3}$$

where w_{ji} is the weight associated with the directed edge from $j \in V$ to $i \in V$, and x_{ji} is equal to 1 if the edge from j to i exists in the set E and it is equal to 0 otherwise. $D_j^{(out)}$ is the weighted outdegree centrality of node j, $PR_j^{(out)}$ is the weighted pagerank outdegree centrality score of j, n is the number of nodes in the network, and $\gamma \in [0, 1]$ is a damping factor ensuring the algorithm will not be forced to terminate. We can modify Eq. (3) to define the weighted pagerank indegree centrality $PR_i^{(in)}$ of node i as:

$$PR_i^{(in)} = \gamma \sum_{i \neq j \in V} \frac{w_{ij} x_{ij}}{D_j^{(in)}} PR_j^{(in)} + \frac{1-\gamma}{n} \tag{4}$$

Results

The Medicus network includes 10 types of agents, 67 nodes and 306 edges or interactions. There were 23 buyers (34%), 22 sellers (33%), 8 brokers (12%), and 14 Medicus clinic staff members (21%). Figure 1 presents the type of interactions and agents observed in the network. Of 306 edges, 67% of the interactions were surgical related, 17% were laundering interactions, and 16% were brokering interactions.

Table 5 Weighted Outdegree Centrality Statistics by Agent Category

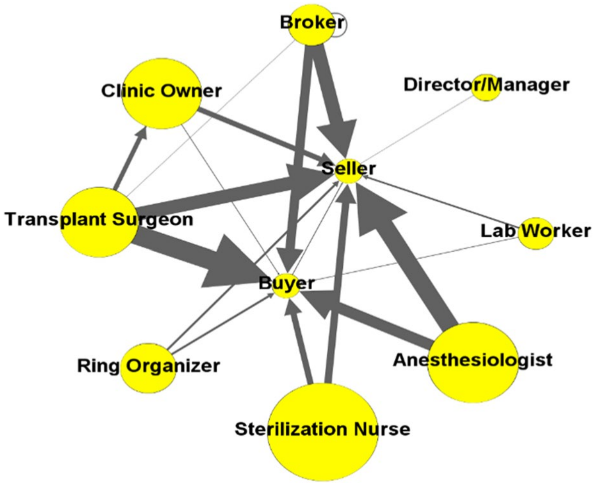
Agent Category	No. of agents	Sum of weighted outdegree centrality	% of weighted outdegree centrality	Average of weighted outdegree centrality	SD of weighted outdegree centrality
Anesthesiologist	3	80	24.02	26.67	8.96
Broker	8	64	19.22	8.00	4.57
Buyer	23	2	0.60	0.09	0.29
Clinic Owner	1	22	6.61	22.00	N/A
Director/Manager	1	1	0.30	1.00	N/A
Lab Worker	2	7	2.10	3.50	4.95
Ring Organizer	1	12	3.60	12.00	N/A
Seller	22	3	0.90	0.14	0.35
Sterilization Nurse	1	35	10.51	35.00	NA
Transplant Surgeon	5	107	32.13	21.40	29.43

The following sections presents the results of betweenness, and pagerank centrality measures. In the calculations of these measures, we removed miscellaneous interactions, as defined in Table 3, as the nature of interactions were unclear for these edges.

Degree centrality

The weighted degree centrality scores were calculated for both outdegree and indegree node connections. Table 5 shows the summary of the weighted *outdegree* centrality statistics by agent category. Transplant surgeons had the highest sum and proportion of weighted outdegree centrality measures ($D = 107$, and 32% respectively), followed by anesthesiologists ($D = 80$, and 24%). The high standard deviation (SD) of the outdegree centrality score of the transplant surgeons ($SD = 29.43$), however, indicates that the outdegree interactions are heavily skewed, implying that there were specific transplant surgeon/s who played a disproportionally larger role in initiating contacts. One sterilization nurse initiated 35 interactions with other agents in the network, recording the highest average weighted outdegree centrality score ($D = 35.00$). Three anesthesiologists also had a relatively high score of average weighted outdegree centrality ($D = 26.67$), followed by clinic owner ($D = 22.00$), and transplant surgeons ($D = 21.40$). Brokers, on average, played a relatively minor role in initiating interactions. Eight brokers initiated 64 (19%) interactions in total and 8 interactions on average. Buyers ($D = 0.09$) and sellers ($D = 0.14$) had the lowest average weighted

Fig. 2 Medicus Network with Average Weighted Outdegree Centrality Scores of Agent Categories



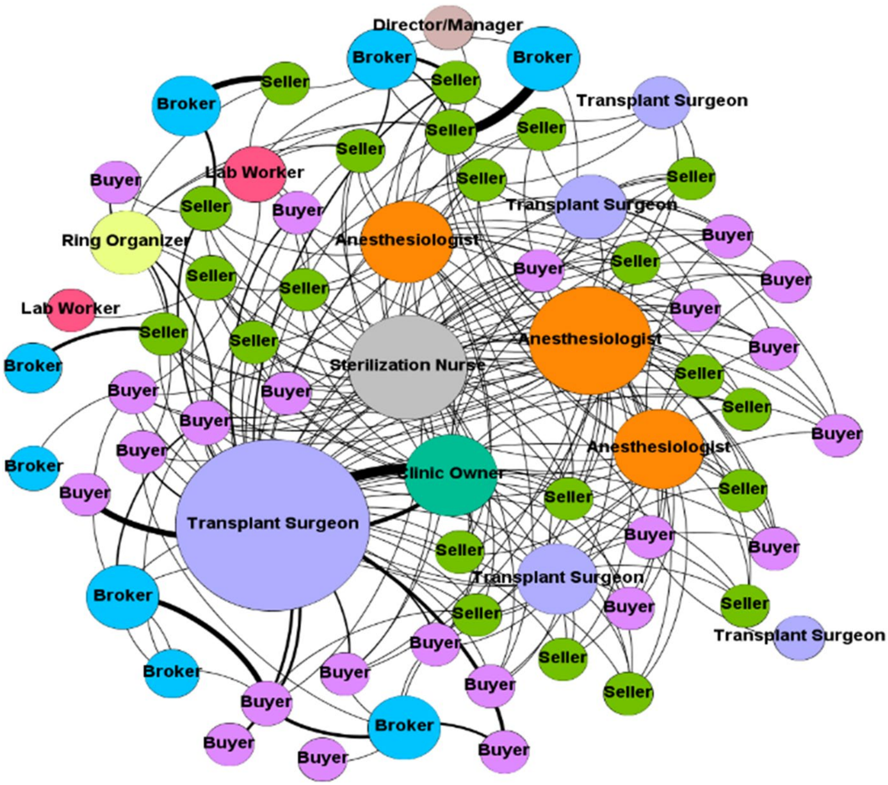


Fig. 3 Medicus Network with Average Weighted Outdegree Centrality Scores of Agents

Table 6 Weighted Indegree Centrality Statistics by Agent Category

Agent Category	No. of agents	Sum of weighted indegree centrality	% of weighted indegree centrality	Average of weighted indegree centrality	SD of weighted indegree centrality
Anesthesiologists	3	0	0.00	0.00	0.00
Broker	8	4	1.20	0.50	0.53
Buyer	23	139	41.74	6.04	2.74
Clinic Owner	1	12	3.60	12.00	N/A
Director/Manager	1	0	0.00	0.00	N/A
Lab Worker	2	1	0.30	0.50	0.71
Ring Organizer	1	0	0.00	0.00	N/A
Seller	22	171	51.35	7.77	3.77
Sterilization Nurse	1	0	0.00	0.00	N/A
Transplant Surgeon	5	6	1.80	1.20	2.68

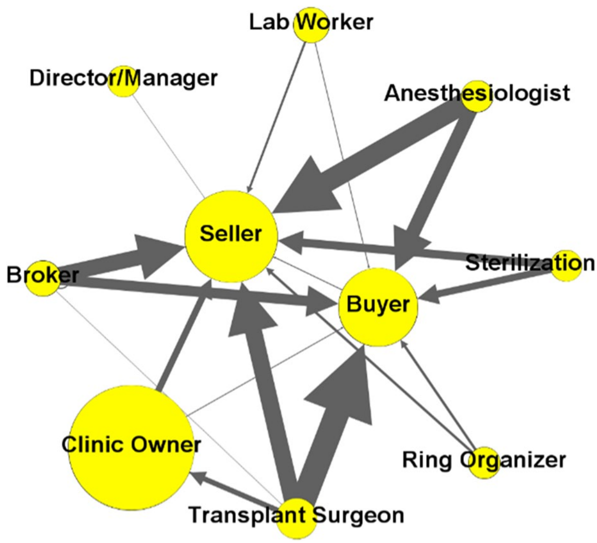
outdegree scores in the network, each with a small SD ($SD = 0.29$ and $SD = 0.35$, respectively).

Figure 2 illustrates the network showing the average weighted outdegree centrality scores of each agent category. In the figure, the node size represents the score of the agent category while the edge width represents the number of interactions, i.e., weight, between the two agent categories. The figure confirms that the medical and clinical agents (sterilization nurses, transplant surgeons, anesthesiologists, and clinic owner) are, on average, the major contact initiators in the network. The network also demonstrates that sellers and buyers, particularly sellers, were the agents with the most interactions. Interestingly, transplant surgeons initiated more contacts to buyers than to sellers, while most other types of agents (brokers, anesthesiologists, clinic owner, and lab workers) initiated contacts more to sellers than to buyers, possibly indicating preexisting connections between transplant surgeons and buyers/patients.

Figure 3 presents a network in which every node represents an agent instead of agent category. The figure confirms that the distribution of the weighted outdegree centrality measure is highly skewed towards one specific transplant surgeon. The figure also shows that interactions initiated by this specific transplant surgeon predominantly involved buyers rather than sellers, while this tendency does not seem to hold for other transplant surgeons. This particular transplant surgeon also appears to be the primary contact of the clinic owner. The network also seems to indicate that there are two types of brokers, i.e., those who initiate contacts only with sellers and others who initiated contacts only with buyers.

Table 6 shows the summary of the weighted *indegree* centrality statistics by agent category. As suspected, sellers and buyers were the recipients of the 93% (51% and 42%, respectively) of the contacts initiated by other agent categories. Sellers were, on average, contacted more than buyers ($D = 7.77$ and $D = 6.04$, respectively)

Fig. 4 Medicus Network with Average Weighted Indegree Centrality Scores of Agent Categories



although SD for sellers was somewhat higher than that for buyers (3.77 vs. 2.74), indicating that some sellers were contacted more than other sellers. The clinic owner received the highest average score of incoming contacts ($D = 12$).

Figure 4 visualizes the network showing the average weighted *indegree* centrality scores of each agent category by the node size. The figure confirms that sellers and buyers along with the clinic owner were major recipients of the interactions in the network.

Figure 5 shows the average weighted *indegree* centrality network of every node instead of every agent category. The figure confirms that, in general, the number of contacts received by sellers vary more than that received by buyers. In particular, one seller seems to receive contacts from other sellers in addition to the contacts initiated by other types of agents (brokers, lab workers and sterilization nurse). One transplant surgeon also appears to have received more contacts than other transplant surgeons. All other agents seem to have received a similar number of incoming contacts within each category.

Betweenness centrality

Table 7 presents the summary of weighted betweenness centrality statistics by agent category. In summary, transplant surgeons ($B = 115.33$, 41%) and brokers ($B = 96.83$, 34%) played key roles in bridging agents. High betweenness centrality scores of transplant surgeons and brokers imply that agents were frequent reaching other unconnected agents through transplant surgeons or brokers. The average weighted betweenness centrality measure was higher for transplant surgeons ($B = 23.07$) than for brokers ($B = 12.10$), although SD was also higher for transplant surgeons ($SD = 51.58$) than for brokers ($SD = 19.99$), indicating that some specific transplant surgeon/s had a substantially larger score than other surgeons. Somewhat

Fig. 5 Medicus Network with Average Weighted Indegree Centrality Scores of Agents

unexpectedly, sellers also had a comparatively higher weighted betweenness score ($B = 68.00$, 24%) with the average betweenness score of 3.09 ($SD = 10.99$). Buyers, in contrast, had a low weighted betweenness score ($B = 3.50$, 1%) with the average betweenness score of 0.15 ($SD = 0.63$). All other agent types scored zero for the weighted betweenness centrality measure.

Figure 6 shows the network showing the average weighted betweenness centrality score of each agent category by the node size. The node size confirms that that transplant surgeons and brokers are the most critical types of agents in terms of bridging different agents. The network also shows that sellers, on average, play a more critical role in connecting agents than buyers. Figure 7 allows us to further interpret the average betweenness scores. It indicates that the high average score of transplant surgeons is mainly attributable to the key transplant surgeon who appears

Table 7 Weighted Betweenness Centrality Statistics by Agent Category

Agent Category	No. of agents	Sum of weighted betweenness centrality	% of weighted betweenness centrality	Average of weighted betweenness centrality	SD of weighted betweenness centrality
Anesthesiologists	3	0.00	0.00	0.00	0.00
Broker	8	96.83	34.14	12.10	19.99
Buyer	23	3.50	1.23	0.15	0.63
Clinic Owner	1	0.00	0.00	0.00	NA
Director/Manager	1	0.00	0.00	0.00	NA
Lab Worker	2	0.00	0.00	0.00	0.00
Ring Organizer	1	0.00	0.00	0.00	NA
Seller	22	68.00	23.97	3.09	10.99
Sterilization Nurse	1	0.00	0.00	0.00	NA
Transplant Surgeon	5	115.33	40.66	23.07	51.58

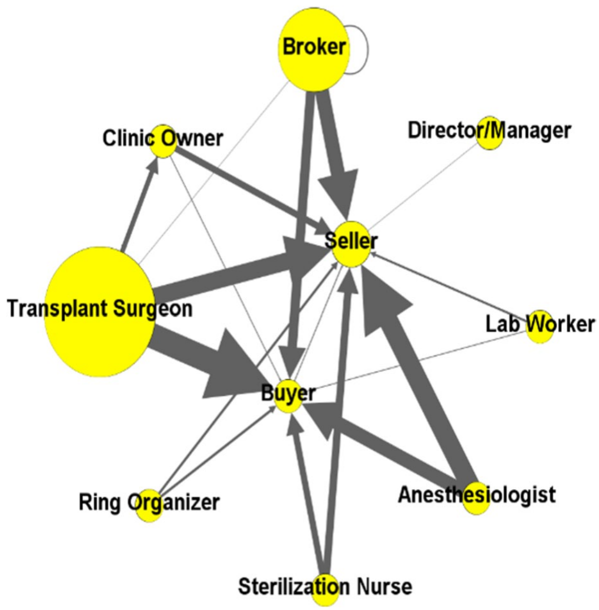


Fig. 6 Medicus Network with Average Weighted Betweenness Centrality Scores of Agent Categories

to operate as the sole conduit to many buyers. It also indicates that some sellers are connected to other sellers, thereby increasing the betweenness score of the category. It also shows that one seller (a relatively large seller node situated in the NE quadrant) operates as the conduits to multiple buyers and sellers and is the sole link to the director/manager. In contrast, buyers tend not to be connected to other buyers, and are likely to be connected only to brokers.

Pagerank centrality

The pagerank centrality score measures the importance of the neighbor nodes (weighted indegree or outdegree scores) that a node is connected to. When a node is connected to other nodes with a high degree weighted score, the node tends to have a high weighted pagerank centrality score. Table 8 presents the summary of weighted pagerank *outdegree* centrality statistics by agent category. The scores of the sum of the weighted pagerank centrality indicates that both sellers and buyers, but particularly sellers, have a high score ($PG = 0.39$, 39% and $PG = 0.33$, 33%, respectively), followed by brokers ($PG = 0.13$, 13%). All other agent categories had substantially smaller pagerank centrality scores ranging between 0.01 and 0.03. On average, however, all agent categories had similar average pagerank centrality scores ranging between 0.010 (Anesthesiologist, Director/Manager, Ring Organizer, and Sterilization Nurse) and 0.018 (Seller). The high score of the average pagerank centrality score among sellers is attributable to the facts that sellers are the main contact recipients of sterilization nurses, anesthesiologists,

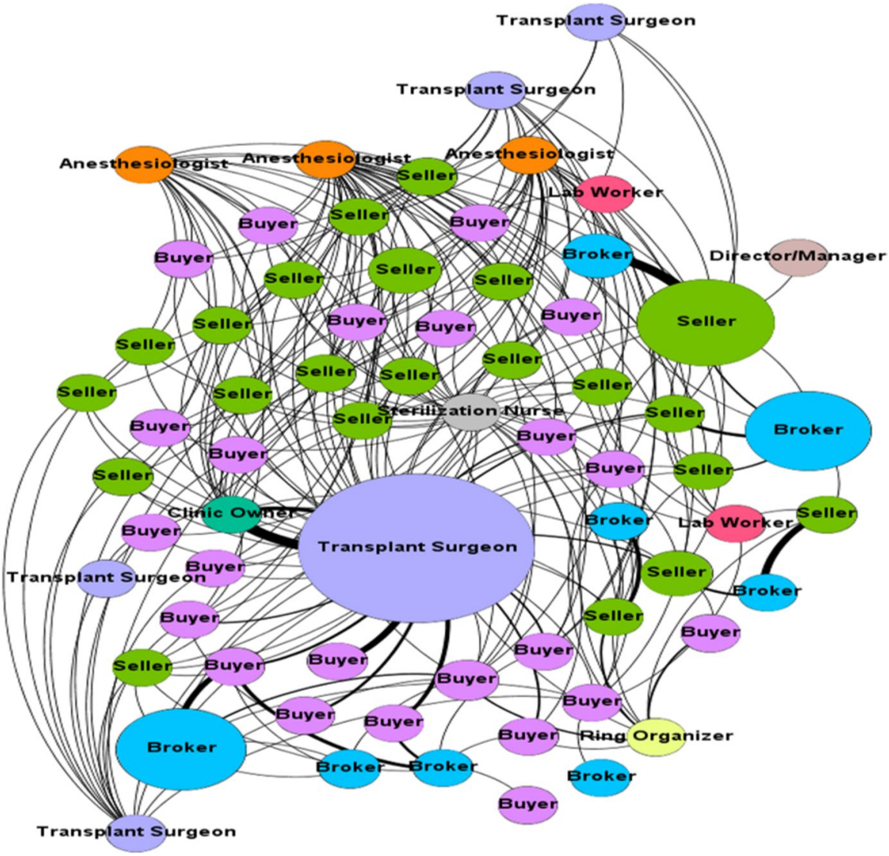


Fig. 7 Medicus Network with Average Weighted Betweenness Centrality Scores of Agents

and clinic owner whose average weighted outdegree centrality scores are relatively high.

Figure 8 confirms that sellers have the highest score of the average weighted pagerank centrality score, followed by brokers and lab workers and then by buyers. Figure 9 highlights several points. First, the score seems to vary rather significantly within the sellers, indicating that there are several sellers that were particularly connected to the nodes with a high average weighted outdegree centrality score. While it is not clearly discernable from the figure, it seems that those sellers are more likely to be the ones that are connected to medical staff. Similarly, the figure highlights that one broker has a significantly higher score of the average weighted pagerank outdegree centrality than other brokers.

Table 9 presents the summary of weighted pagerank *indegree* centrality statistics by agent category. The scores of the sum of the weighted pagerank centrality indicates that brokers by far have the highest sum (0.310) and the percentage (31%) of weighted pagerank *indegree* centrality score. One average, clinic owner had the highest weighted

Table 8 Weighted PageRank Outdegree Centrality Statistics by Agent Role

Agent Category	No. of agents	Sum of weighted pagerank outdegree centrality	% of weighted pagerank outdegree centrality	Average of weighted pagerank outdegree centrality	SD of weighted pagerank outdegree centrality
Anesthesiologist	3	0.030	3.05	0.010	0.000
Broker	8	0.126	12.62	0.016	0.013
Buyer	23	0.325	32.53	0.014	0.004
Clinic Owner	1	0.012	1.20	0.012	NA
Director/Manager	1	0.010	1.02	0.010	NA
Lab Worker	2	0.031	3.12	0.016	0.008
Ring Organizer	1	0.010	1.02	0.010	NA
Seller	22	0.390	39.02	0.018	0.009
Sterilization Nurse	1	0.010	1.02	0.010	NA
Transplant Surgeon	5	0.054	5.41	0.011	0.001

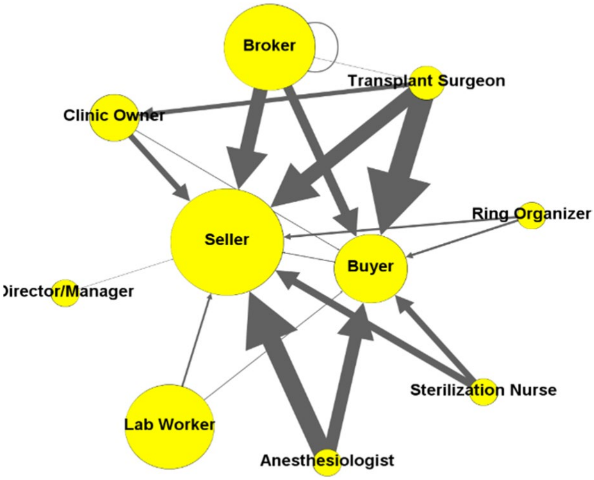


Fig. 8 Medicus Network with Average Weighted PageRank Outdegree Centrality Scores of Agent Categories

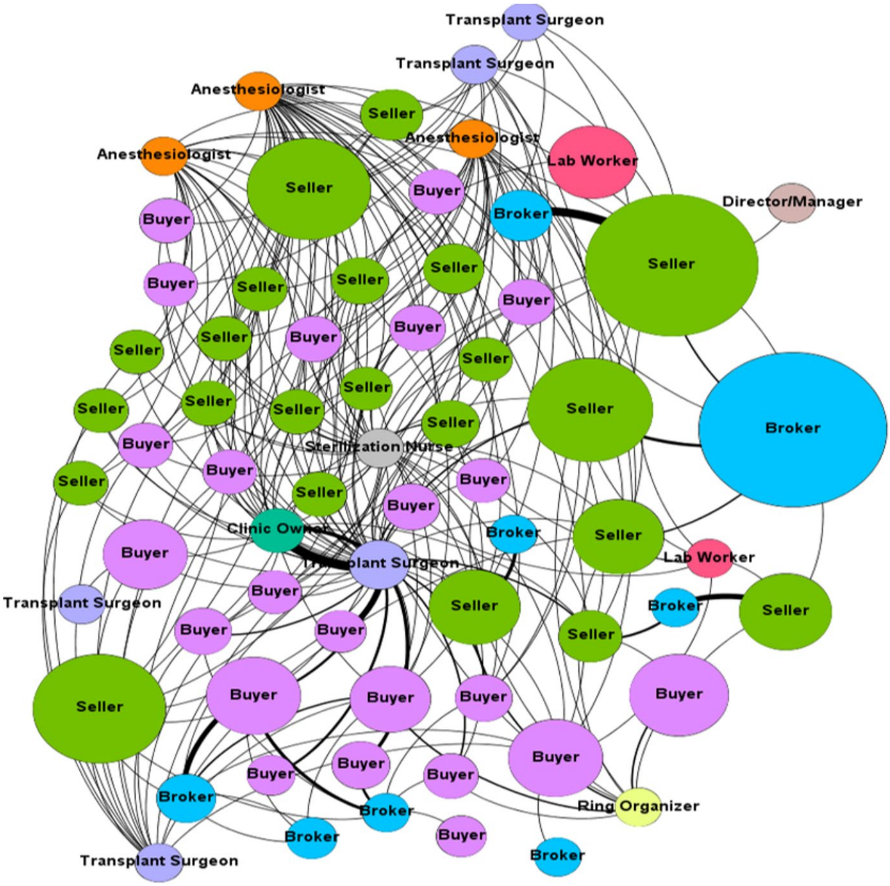
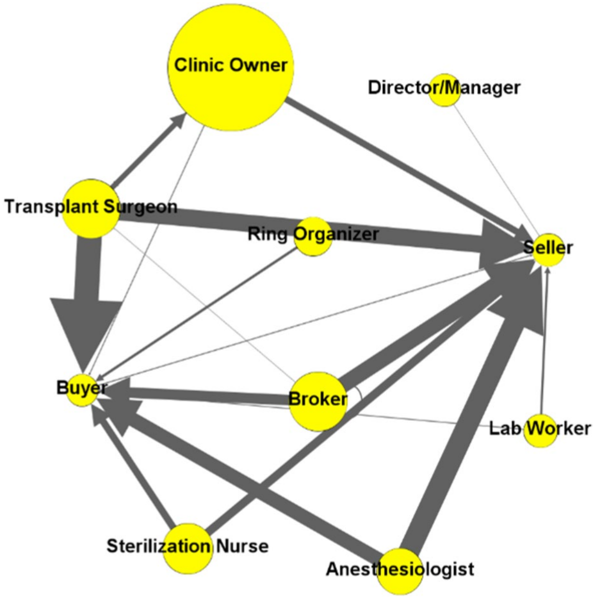


Fig. 9 Medicus Network with Average Weighted PageRank Outdegree Centrality Scores of Agent

Table 9 Weighted PageRank Indegree Centrality Statistics by Agent Category

Agent Category	No. of agents	Sum of weighted pagerank indegree centrality	% of weighted pagerank indegree centrality	Average of weighted pagerank indegree centrality	SD of weighted pagerank indegree centrality
Anesthesiologist	3	0.069	6.94	0.023	0.006
Broker	8	0.310	31.03	0.039	0.049
Buyer	23	0.112	11.18	0.005	0.000
Clinic Owner	1	0.123	12.34	0.123	NA
Director/Manager	1	0.006	0.58	0.006	NA
Lab Worker	2	0.014	1.37	0.007	0.003
Ring Organizer	1	0.014	1.36	0.014	NA
Seller	22	0.131	13.09	0.006	0.004
Sterilization Nurse	1	0.028	2.83	0.028	NA
Transplant Surgeon	5	0.193	19.28	0.039	0.063

Fig. 10 Medicus Network with Average Weighted PageRank Indegree Centrality Scores of Agents



pagerank *indegree* centrality score (0.123), presumably because the agent is connected to the agents with a relatively high score of average indegree centrality, i.e., the transplant surgeon, sellers and buyers. Brokers also had a relatively high weighted pagerank *indegree* centrality score (0.039) together with transplant surgeons (0.039) again due to their high connectivity to sellers and buyers.

Figure 10 confirms that clinical owner who are connected to transplant surgeon, sellers, and buyers has by far the highest average score of average weighted pagerank indegree centrality score. Figure 11 demonstrates that the variation is the scores is high among brokers and transplant surgeons. One transplant surgeon with a particularly high frequency of interactions with the clinic owner and buyers has a significantly higher score of the weighted pagerank indegree centrality. Similarly, one broker who is connected to the clinic owner and another broker who is connected to the broker seem to have a higher score of the weighted pagerank indegree centrality in the network.

Discussion

The current paper presented the first systematic analysis of an organ trade network using SNA. Our findings confirmed the findings of the previous analysis (Albarán et al. 2017) which determined that the medical team was the most central part of the network and that, if the clinic was closed, the network would collapse. While we agree to this conclusion, we additionally found that the clinical owner—who was a

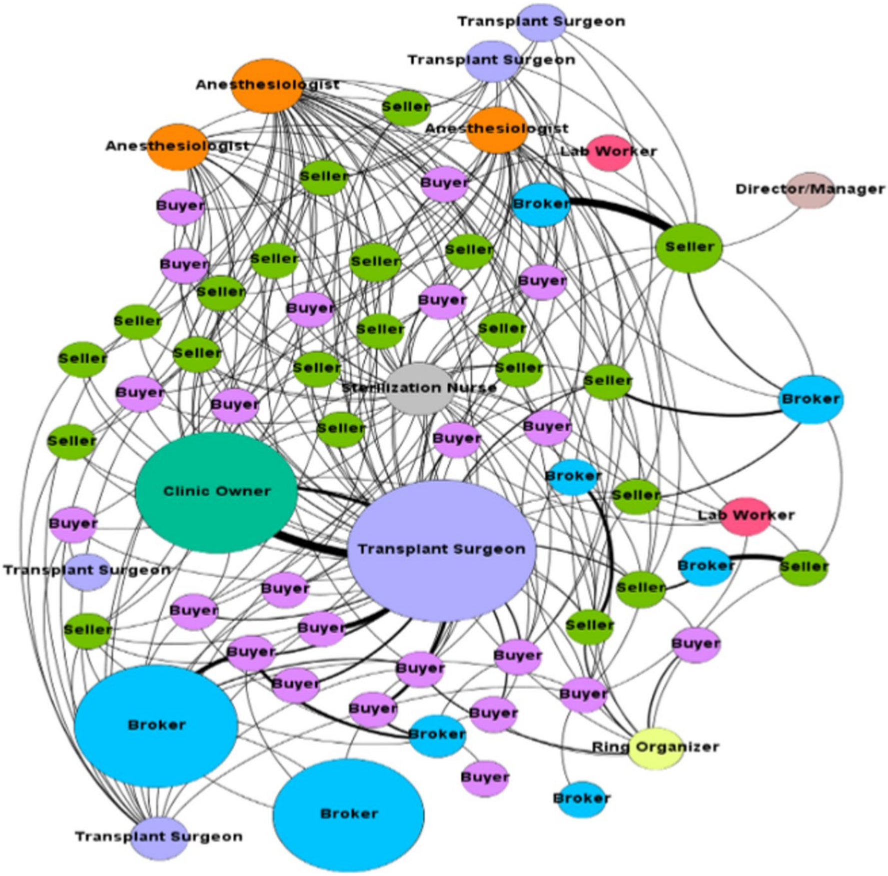


Fig. 11 Medicus Network with Average Weighted PageRank Indegree Centrality Scores of Agents

major contact recipient—was contacted only by a specific transplant surgeon who played the major role in this network. This was reflected in the very high score of betweenness centrality statistics of the transplant surgeon. This additional finding indicates that the challenge in identifying the clinic and the clinic owner, which is only possible by the identification of the transplant surgeon. The roles played by other transplant surgeons were substantially minor compared both to the main transplant surgeon and to other agent categories regardless of the type of centrality scores that we calculated.

It is of note that brokers often played a secondary role in the network, even in initiating contacts to sellers and buyers. This could indicate that brokers in this network were outsourced employees by medical staff rather than being the major part of the crime. This may be reflected in the fact that the brokers who were in contact with buyers were often different from the brokers who were in contact with sellers, thereby preventing each broker from playing a multifaceted role and grasping a larger picture of the crime. In particular, we observed that brokers initiate more contacts to sellers than to buyers. A large number of interactions to buyers were in fact initiated by the main transplant surgeon, presumably because he had the pre-existing doctor-patient relationship with them. It appears that the network remained this way rather than him hiring brokers to whom he could delegate this role. These patterns and the relative importance of actors are very similar to the ones observed in the Costa Rica's kidney trade case of 2017 (file no. 13–000227-1219-PE; sentence no. 989–2017). In this case, the main transplant surgeon—Dr. Francisco José Mora Palma, former head of nephrology at the publicly-run Rafael Ángel Calderón Guardia Hospital—was the key player in the network, while the brokers played a secondary role. According to the investigations and trial, Dr. Mora Palma and his accomplices (three other doctors, a Greek businessman, and a National Police officer) sold kidneys through brokers to recipients in Israel, Ukraine and other countries from 2009 to 2013 (Studdert-Kennedy 2019).

The comparison of the roles played by sellers and brokers revealed that sellers play a larger role regardless of the type of the centrality measure we refer to. The centrality scores were higher for sellers than for buyers for all statistics, including the average weighted outdegree centrality ($D=0.14$ vs. $D=0.09$), the average weighted indegree centrality ($D=7.77$ vs. $D=6.04$), the average betweenness centrality ($B=3.09$ vs. $B=0.15$), the average weighted pagerank outdegree centrality (0.08 vs. 0.014), and the average weighted pagerank indegree centrality ($PG=0.006$ vs. $PG=0.005$). It is likely that this reflects the fact that sellers are more likely to get involved in a network after they sell their kidneys, by referring to new potential sellers. Such incidences are reported in not only in kidney trafficking networks (Columb 2020; Yea 2010) but also in other types of trafficking networks such as sex trafficking where the victims subsequently become a "madam", actively recruiting other potential victims (Kotiswaran 2008; Mancuso 2014). In fact, the materials we reviewed indicated that it was common for brokers to offer sellers an opportunity to recruit others to be sellers after their return home, while the connections between brokers and buyers tend to end with their returning home.

We also found that the clinic owner and the director had a zero score of weighted betweenness centrality. This is significant divergence from the findings of Albaran et al. (2017), who determined that the director was the most betweenness agent and represented the nucleus of the network. Part of the reason is that our project constructed more detailed information of the network, compared with Albaran et al.'s study. Our project includes weighted edge directions while Albaran et al.'s study seems only calculates betweenness scores based on the undirected network. A further discrepancy was found between our study and Albaran et al. in that Albaran et al. only listed two brokers while we identified eight. The difference in the number is important if you consider that the brokers occupied a large proportion of intermediators of the shortest path in the network, as evidenced in a relatively high average betweenness centrality score of the brokers. When those brokers act to potentially control information flow, there is a possibility that these brokers could grow to become more powerful in the network. Since the Costa Rica's kidney trade case of 2017 seems to observe similar trends, the two kidney trade networks might be comparable as well. It would be interesting to replicate a study of this kind to analyze the Costa Rican case.

Our analysis also indicated that there are significant variations in several centrality scores. Specifically, we observed that outdegree centrality varied significantly in transplant surgeons, the indegree centrality scores varied significantly in sellers, the between centrality scores varied significantly in transplant surgeons and moderately in sellers and brokers, and the pagerank outdegree centrality scores vary relatively significantly in sellers and brokers. These high variations in the centrality scores have been noted in the SNA analysis of a different trafficking network. A study of a Nigerian sex trafficking network (Mancuso 2014) found that, in contrast to the assumption that all madams play an equally central role, there is a significant disparity in the level of influence a given madame may have compared to another. In relation to this, Mancuso identified two main groups of Madams which are distinguished by the amount of human and social capital they had. Two women in the network may have equal structural position (social capital), but their comparative influence within that equal position is defined by their access to resources such as family ties (human capital). Similar subgroups may exist in kidney trafficking. In particular, in the Medicus case, the particular transplant surgeon held far more human capital including his tie to the clinic owner. Similarly, some sellers appear to own more ties to other sellers, thereby leveraging their human capital.

Our results indicate that SNA is a promising tool for understanding these criminal networks, and that further study should be done to test its merits. Outside organ trafficking, more applications of SNA are found. In the criminal justice field, SNA has proven its usefulness in providing an objective perspective about the network structure, such as the level of connectedness between various types of agents in a network. It is reported that the impartial perspective can be useful during a criminal investigation as a tool to complement the experience and problem-solving skills of law enforcement professionals (Cockbain et al. 2011). But even a post-investigation analysis can be highly beneficial as the results can challenge common narratives. Hughes et al. (2017), for instance, used SNA in their study of multiple drug trading networks and found that poly-drug trafficking networks (networks that manufacture and distribute multiple types of drugs instead of only one) have common features of division and labor and a clear management structure. This feature of management systems was contrary to much of the other literature on drug-trafficking social networks. Further, in the study of 4 different terrorist clusters (or “cells”) that have operated in or against Australia, Koschade (2007) found “that cells with a focus on efficiency rather than covertness were more successful in achieving their objectives (contrary to popular belief).” SNA is also helpful in revealing influential agents. In a study seeking to identify the most harmful co-offenders in Denmark, Frydensberg et al. (2019) looked at vast data about offending criminals over the course of several years. They added evidence to the previously discerned “Pareto curve” phenomenon (Sherman 2007) when they found that a “power few” of 7.42% of the co-offending population were responsible for half of all the crimes in the studied time period.

There are several limitations to our study, most of which pertain to the nature of the source material. Because the source material is a summary of the court proceedings, we have only a small portion of all potential information regarding interactions between the network agents. The document declares who was found guilty of what charges, and the witness testimonies and other information contained in the summary are contained for their relevance to the conclusions of the court. Some people receive more attention than others, which might have disproportionately affected their appearance in the network. The same seems to have happened in the case of Costa Rica. The 2017 case is closed, but investigations of a second kidney trade initiated in 2019 (Studdert-Kennedy 2019), and there is a possibility that the network discovered a couple of years earlier is in reality much more complex. Further research needs to be done in this regard as the two kidney trade networks may be related.

Conclusion

Due to the highly specialized skill set required for performing a kidney transplant, a kidney trafficking network inevitably has at least one sizeable cluster consisting of various medical staff. Brokers appear to play a secondary role and tend to play a specific role with limited influence in the trafficking operation. Sellers, in general, played a bigger role than buyers, with several sellers playing a more significant role than others. The implication for law enforcement is that identifying the agents, particularly brokers and sellers who connect different types of agents is likely to be more effective than putting effort to identify the clinic/s where transplants take place. We should note, however, that this approach may not apply to other forms of trafficking or smuggling due to the unique nature of a kidney trafficking network that requires technical skills.

Our analysis indicates that SNA is a promising tool to gain systematic knowledge about the structure and the pattern of organ trafficking networks. We are aware that, as the first study of its kind, the findings of the current study cannot be generalized at this point. Further investigations of other kidney/organ trafficking cases are warranted to see how generalizable the findings of the current study may be. Here, the kidney trafficking case in Costa Rica during 2017 may be a good candidate, as they seem to exhibit resemblances to the patterns observed in the current study although at a larger scale (Studdert-Kennedy 2019). From the analytical point of view, we acknowledge that criminal networks are dynamic (Bright 2015), and future endeavor should include the use of dynamic network analysis (e.g., ERGM or SAM) to fathom how network changes relate to behavioral shifts (Carley 2003). Finally, we note that SNA should always be complemented with qualitative discussion to interpret the results correctly and to guide the future directions for the application of this quantitative tool.

Appendix

Agent/Node identification

The table below lists the ID and Label by which each agent is known. The ID was created to have a short code to represent each agent when recording the interactions between them. The Label is the primary job that the agent had in the network.

Table 10 ID and Label for network agents

ID	Label
K1	Recipient
K2	Recipient
K3	Donor
K4	Director/Manager
K6	Donor
K7	Donor
K8	Donor
K9	Donor
K10	Broker
K14	Recipient
K15	Recipient
K18	Broker
K19	Transplant Surgeon
K20	Transplant Surgeon
K22	Donor
K23	Recipient
K24	Broker
K25	Recipient
K26	Donor
K27	Recipient
K29	Anaesthesiologist
K31	Broker
K32	Donor
K33	Transplant Surgeon
K35	Recipient
K36	Owner of the Medicus Clinic
K37	Recipient
K38	Lab worker
K39	Recipient
K40	Recipient
K41	Donor
K42	Organizer of the organ trafficking ring
K43	Recipient
K44	Donor
K46	Recipient
K47	Donor
K48	Recipient
K49	Transplant Surgeon
K50	Recipient
K51	Donor
K52	Donor
K54	Recipient
K55	Anaesthesiologist
K56	Anaesthesiologist

Table 10 (continued)

ID	Label
K57	Broker
K58	Sterilization Nurse
K61	Recipient
K63	Recipient
K64	Recipient
K67	Recipient
K68	Donor
K70	Broker
K71	Donor
K73	Donor
K74	Lab worker
K75	Recipient
K76	Donor
K77	Donor
K78	Donor
K79	Donor
K82	Recipient
K88	Donor
K89	Donor
K90	Recipient
K91	Broker
K93	Transplant Surgeon
K95	Broker

Data set for the analysis

The table below contains the data used to visualize the Medicus network in *Gephi* for the analysis. Source represents the acting agent, and Target represents the receiving agent. The Page # tells the reader where to look for information about the interaction in the source material *In the Name of the People*. The information may not be on that exact page, because the page number, for example, may reference the beginning of the witness testimony wherein the information can be found. A row of Table 6 would read: "K29 had one surgical interaction with K27, whose transplant took place on 3/8/2008. The information about this interaction can be found on page 89 of *In the Name of the People*."

Table 11 Interactions between agents

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K36	K93	LAUND	1	0	2/15/2007	96
K93	K36	LAUND	1	0	12/13/2007	96
K36	K93	LAUND	1	0	12/21/2007	96
K93	K36	LAUND	1	0	12/22/2007	96
K93	K36	LAUND	1	0	12/25/2007	96
K36	K93	LAUND	1	0	1/6/2008	96
K93	K36	LAUND	1	0	1/6/2008	96
K93	K36	LAUND	1	0	1/22/2008	96
K93	K36	LAUND	1	0	1/23/2008	96
K93	K36	LAUND	1	0	1/30/2008	96
K93	K36	LAUND	1	0	2/5/2008	96
K93	K36	LAUND	1	0	2/13/2008	96
K93	K36	LAUND	1	0	2/13/2008	96
K93	K36	LAUND	1	0	2/15/2008	96
K93	K36	LAUND	1	0	3/4/2008	96
K29	K27	SURG	1	1	3/8/2008	89
K29	K68	SURG	1	1	3/8/2008	89
K33	K27	SURG	1	1	3/8/2008	89
K36	K68	SURG	1	1	3/8/2008	89
K55	K27	SURG	1	1	3/8/2008	89
K55	K68	SURG	1	1	3/8/2008	89
K56	K27	SURG	1	1	3/8/2008	89
K56	K68	SURG	1	1	3/8/2008	89
K58	K27	SURG	1	1	3/8/2008	106
K58	K68	SURG	1	1	3/8/2008	106
K93	K27	SURG	1	1	3/8/2008	89
K93	K68	SURG	1	1	3/8/2008	89
K36	K93	LAUND	1	0	4/29/2008	96
K36	K93	LAUND	1	0	5/6/2008	96
K19	K46	SURG	1	2	5/11/2008	89
K29	K51	SURG	1	2	5/11/2008	89
K36	K51	SURG	1	2	5/11/2008	89
K55	K46	SURG	1	2	5/11/2008	89
K55	K51	SURG	1	2	5/11/2008	89
K56	K46	SURG	1	2	5/11/2008	89
K56	K51	SURG	1	2	5/11/2008	89
K58	K46	SURG	1	2	5/11/2008	106
K58	K51	SURG	1	2	5/11/2008	106
K93	K46	SURG	1	2	5/11/2008	89
K93	K51	SURG	1	2	5/11/2008	89
K18	K78	BRKR	1	3	5/15/2008	51
K18	K78	BRKR	1	3	5/15/2008	51

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K19	K54	SURG	1	3	5/15/2008	89
K29	K54	SURG	1	3	5/15/2008	89
K29	K78	SURG	1	3	5/15/2008	89
K36	K78	SURG	1	3	5/15/2008	89
K42	K78	LAUND	1	3	5/15/2008	51
K55	K54	SURG	1	3	5/15/2008	89
K55	K78	SURG	1	3	5/15/2008	89
K56	K54	SURG	1	3	5/15/2008	89
K56	K78	SURG	1	3	5/15/2008	89
K58	K54	SURG	1	3	5/15/2008	106
K58	K78	SURG	1	3	5/15/2008	106
K78	K74	BRKR	1	3	5/15/2008	51
K93	K54	SURG	1	3	5/15/2008	89
K93	K78	SURG	1	3	5/15/2008	89
K10	K64	BRKR	1	4	6/4/2008	67
K10	K93	BRKR	1	4	6/4/2008	68
K29	K44	SURG	1	4	6/4/2008	89
K29	K64	SURG	1	4	6/4/2008	89
K33	K64	SURG	1	4	6/4/2008	89
K36	K44	SURG	1	4	6/4/2008	89
K38	K64	BRKR	1	4	6/4/2008	68
K55	K44	SURG	1	4	6/4/2008	89
K56	K44	SURG	1	4	6/4/2008	89
K56	K64	SURG	1	4	6/4/2008	89
K58	K44	SURG	1	4	6/4/2008	106
K58	K64	SURG	1	4	6/4/2008	106
K70	K64	LAUND	1	4	6/4/2008	89
K93	K44	SURG	1	4	6/4/2008	89
K93	K64	SURG	1	4	6/4/2008	89
K29	K71	SURG	1	5	6/5/2008	89
K36	K71	SURG	1	5	6/5/2008	89
K55	K71	SURG	1	5	6/5/2008	89
K56	K71	SURG	1	5	6/5/2008	89
K58	K71	SURG	1	5	6/5/2008	106
K93	K71	SURG	1	5	6/5/2008	89
K19	K90	SURG	1	6	6/6/2008	89
K29	K90	SURG	1	6	6/6/2008	89
K56	K90	SURG	1	6	6/6/2008	89
K58	K90	SURG	1	6	6/6/2008	106
K93	K90	SURG	1	6	6/6/2008	89
K18	K77	BRKR	1	7	6/19/2008	51

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K18	K77	BRKR	6	7	6/19/2008	51
K29	K67	SURG	1	7	6/19/2008	89
K33	K67	SURG	1	7	6/19/2008	89
K36	K67	SURG	1	7	6/19/2008	89
K38	K77	BRKR	1	7	6/19/2008	51
K42	K77	LAUND	1	7	6/19/2008	51
K56	K67	SURG	1	7	6/19/2008	89
K67	K10	BRKR	7	7	6/19/2008	68
K91	K77	LAUND	1	7	6/19/2008	51
K93	K67	BRKR	1	7	6/19/2008	68
K93	K67	SURG	1	7	6/19/2008	89
K95	K67	LAUND	1	7	6/19/2008	89
K19	K25	SURG	1	8	6/20/2008	89
K29	K25	SURG	1	8	6/20/2008	89
K33	K25	SURG	1	8	6/20/2008	89
K33	K8	SURG	1	8	6/20/2008	89
K55	K8	SURG	1	8	6/20/2008	89
K56	K25	SURG	1	8	6/20/2008	89
K56	K8	SURG	1	8	6/20/2008	89
K58	K25	SURG	1	8	6/20/2008	106
K58	K8	SURG	1	8	6/20/2008	106
K93	K25	SURG	1	8	6/20/2008	89
K93	K8	SURG	1	8	6/20/2008	89
K10	K40	LAUND	1	9	7/2/2008	69
K19	K7	SURG	1	9	7/2/2008	89
K36	K7	SURG	1	9	7/2/2008	89
K49	K7	SURG	1	9	7/2/2008	89
K55	K7	SURG	1	9	7/2/2008	89
K56	K7	SURG	1	9	7/2/2008	89
K58	K7	SURG	1	9	7/2/2008	106
K93	K40	BRKR	1	9	7/2/2008	69
K93	K40	LAUND	3	9	7/2/2008	69
K93	K7	SURG	1	9	7/2/2008	89
K95	K40	LAUND	3	9	7/2/2008	69
K10	K1	LAUND	1	10	7/3/2008	71
K29	K73	SURG	1	10	7/3/2008	89
K36	K73	SURG	1	10	7/3/2008	89
K49	K73	SURG	1	10	7/3/2008	89
K55	K73	SURG	1	10	7/3/2008	89
K56	K73	SURG	1	10	7/3/2008	89
K58	K73	SURG	1	10	7/3/2008	106

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K93	K1	LAUND	7	10	7/3/2008	71
K93	K73	SURG	1	10	7/3/2008	89
K95	K1	BRKR	1	10	7/3/2008	71
K95	K37	BRKR	1	10	7/3/2008	72
K33	K26	SURG	1	11	7/22/2008	89
K36	K26	SURG	1	11	7/22/2008	89
K55	K26	SURG	1	11	7/22/2008	89
K56	K26	SURG	1	11	7/22/2008	89
K93	K26	SURG	1	11	7/22/2008	89
K93	K61	BRKR	2	11	7/22/2008	74
K93	K61	BRKR	1	11	7/22/2008	74
K33	K75	SURG	1	12	7/23/2008	89
K36	K75	SURG	1	12	7/23/2008	89
K55	K75	SURG	1	12	7/23/2008	89
K56	K75	SURG	1	12	7/23/2008	89
K93	K75	SURG	1	12	7/23/2008	89
K18	K79	BRKR	3	14	7/24/2008	53
K29	K48	SURG	1	13	7/24/2008	89
K29	K79	SURG	1	14	7/24/2008	89
K29	K82	SURG	1	14	7/24/2008	89
K29	K9	SURG	1	13	7/24/2008	89
K36	K79	SURG	1	14	7/24/2008	89
K36	K9	SURG	1	13	7/24/2008	89
K38	K48	BRKR	1	13	7/24/2008	75
K38	K9	BRKR	1	14	7/24/2008	75
K42	K79	BRKR	1	14	7/24/2008	53
K42	K79	LAUND	1	14	7/24/2008	53
K42	K82	LAUND	1	14	7/24/2008	75
K48	K42	BRKR	8	13	7/24/2008	75
K56	K48	SURG	1	13	7/24/2008	89
K56	K79	SURG	1	14	7/24/2008	89
K56	K82	SURG	1	14	7/24/2008	89
K56	K9	SURG	1	13	7/24/2008	89
K58	K48	SURG	1	13	7/24/2008	106
K58	K79	SURG	1	14	7/24/2008	106
K58	K82	SURG	1	14	7/24/2008	106
K58	K9	SURG	1	13	7/24/2008	106
K79	K35	LAUND	1	14	7/24/2008	75
K93	K48	LAUND	1	13	7/24/2008	89
K93	K48	SURG	1	13	7/24/2008	89
K93	K79	SURG	1	14	7/24/2008	89

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K93	K79	SURG	1	14	7/24/2008	89
K93	K82	SURG	1	14	7/24/2008	89
K93	K9	SURG	1	13	7/24/2008	89
K29	K89	SURG	1	15	7/29/2008	89
K36	K89	SURG	1	15	7/29/2008	89
K56	K89	SURG	1	15	7/29/2008	89
K58	K89	SURG	1	15	7/29/2008	106
K93	K89	SURG	1	15	7/29/2008	89
K10	K39	BRKR	2	16	8/18/2008	77
K33	K3	SURG	1	16	8/18/2008	89
K36	K3	SURG	1	16	8/18/2008	89
K39	K10	BRKR	1.7	16	8/18/2008	77
K42	K39	BRKR	1	16	8/18/2008	77
K55	K3	SURG	1	16	8/18/2008	89
K56	K3	SURG	1	16	8/18/2008	89
K58	K39	SURG	1	16	8/18/2008	106
K93	K3	SURG	1	16	8/18/2008	89
K93	K39	BRKR	1	16	8/18/2008	77
K93	K39	SURG	1	16	8/18/2008	89
K95	K39	BRKR	1	16	8/18/2008	77
K10	K2	BRKR	3	17	8/19/2008	79
K10	K2	LAUND	3	17	8/19/2008	79
K10	K32	LAUND	1	17	8/19/2008	79
K10	K57	BRKR	1	17	8/19/2008	82
K2	K32	LAUND	1	17	8/19/2008	79
K33	K32	SURG	1	17	8/19/2008	89
K33	K76	SURG	1	18	8/19/2008	89
K36	K76	SURG	1	18	8/19/2008	89
K55	K32	SURG	1	17	8/19/2008	89
K55	K76	SURG	1	18	8/19/2008	89
K56	K32	SURG	1	17	8/19/2008	89
K56	K76	SURG	1	18	8/19/2008	89
K57	K2	LAUND	1	17	8/19/2008	79
K58	K2	SURG	1	17	8/19/2008	106
K58	K32	SURG	1	17	8/19/2008	106
K58	K76	SURG	1	18	8/19/2008	106
K93	K2	BRKR	1	17	8/19/2008	79
K93	K2	LAUND	1	17	8/19/2008	79
K93	K2	SURG	1	17	8/19/2008	89
K93	K32	SURG	1	17	8/19/2008	89
K93	K76	SURG	1	18	8/19/2008	89

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K93	K90	BRKR	1	17	8/19/2008	68
K95	K2	BRKR	1	17	8/19/2008	79
K95	K2	LAUND	1	17	8/19/2008	79
K95	K2	LAUND	1	17	8/19/2008	79
K95	K2	LAUND	1	17	8/19/2008	79
K95	K32	LAUND	1	17	8/19/2008	79
K95	K90	LAUND	1	17	8/19/2008	68
K29	K14	SURG	1	19	9/9/2008	89
K29	K47	SURG	1	19	9/9/2008	89
K33	K14	SURG	1	19	9/9/2008	89
K33	K47	SURG	1	19	9/9/2008	89
K38	K47	BRKR	1	19	9/9/2008	55
K42	K47	BRKR	1	19	9/9/2008	55
K56	K14	SURG	1	19	9/9/2008	89
K56	K47	SURG	1	19	9/9/2008	89
K58	K14	SURG	1	19	9/9/2008	106
K58	K47	SURG	1	19	9/9/2008	106
K91	K47	BRKR	2	19	9/9/2008	55
K93	K14	SURG	1	19	9/9/2008	89
K93	K47	SURG	1	19	9/9/2008	89
K10	K63	BRKR	2	20	9/27/2008	81
K19	K41	SURG	1	20	9/27/2008	89
K19	K63	SURG	1	20	9/27/2008	89
K33	K63	SURG	1	20	9/27/2008	89
K36	K41	SURG	1	20	9/27/2008	89
K42	K63	BRKR	2	20	9/27/2008	81
K49	K41	SURG	1	20	9/27/2008	89
K55	K41	SURG	1	20	9/27/2008	89
K55	K63	SURG	1	20	9/27/2008	89
K56	K41	SURG	1	20	9/27/2008	89
K56	K63	SURG	1	20	9/27/2008	89
K57	K10	BRKR	1	20	9/27/2008	82
K57	K63	LAUND	1	20	9/27/2008	81
K58	K41	SURG	1	20	9/27/2008	106
K58	K63	SURG	1	20	9/27/2008	106
K63	K41	LAUND	1	20	9/27/2008	81
K93	K41	SURG	1	20	9/27/2008	89
K93	K63	SURG	1	20	9/27/2008	89
K19	K43	SURG	1	21	9/29/2008	89
K19	K52	SURG	1	21	9/29/2008	89
K29	K52	SURG	1	21	9/29/2008	89

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K55	K43	SURG	1	21	9/29/2008	89
K56	K43	SURG	1	21	9/29/2008	89
K56	K52	SURG	1	21	9/29/2008	89
K58	K43	SURG	1	21	9/29/2008	106
K58	K52	SURG	1	21	9/29/2008	106
K93	K43	SURG	1	21	9/29/2008	89
K93	K52	SURG	1	21	9/29/2008	89
K19	K22	SURG	1	22	10/21/2008	89
K19	K23	SURG	1	22	10/21/2008	89
K22	K91	BRKR	1	22	10/21/2008	57
K24	K22	BRKR	4	22	10/21/2008	57
K24	K22	BRKR	1	22	10/21/2008	57
K24	K22	LAUND	1	22	10/21/2008	57
K24	K22	LAUND	1	22	10/21/2008	57
K24	K22	LAUND	1	22	10/21/2008	57
K24	K22	LAUND	3	22	10/21/2008	57
K24	K23	LAUND	1	22	10/21/2008	57
K38	K22	BRKR	1	22	10/21/2008	57
K4	K22	LAUND	1	22	10/21/2008	57
K42	K22	BRKR	1	22	10/21/2008	57
K49	K22	SURG	1	22	10/21/2008	89
K55	K22	SURG	1	22	10/21/2008	89
K56	K22	SURG	1	22	10/21/2008	89
K56	K23	SURG	1	22	10/21/2008	89
K58	K22	SURG	1	22	10/21/2008	106
K58	K23	SURG	1	22	10/21/2008	106
K91	K22	BRKR	2	22	10/21/2008	57
K91	K24	BRKR	1	22	10/21/2008	57
K93	K22	SURG	1	22	10/21/2008	89
K93	K23	SURG	1	22	10/21/2008	89
K20	K50	SURG	1	23	10/26/2008	89
K29	K6	SURG	1	23	10/26/2008	89
K33	K50	SURG	1	23	10/26/2008	89
K33	K6	SURG	1	23	10/26/2008	89
K38	K6	BRKR	1	23	10/26/2008	61
K49	K6	SURG	1	23	10/26/2008	89
K56	K50	SURG	1	23	10/26/2008	89
K56	K6	SURG	1	23	10/26/2008	89
K58	K50	SURG	1	23	10/26/2008	106
K58	K6	SURG	1	23	10/26/2008	106
K91	K6	BRKR	3	23	10/26/2008	61

Table 11 (continued)

Source	Target	Category	Weight	Transplant ID	Transplant date	Page of Interaction
K91	K6	LAUND	1	23	10/26/2008	61
K93	K50	SURG	1	23	10/26/2008	89
K93	K6	LAUND	1	23	10/26/2008	61
K93	K6	SURG	1	23	10/26/2008	89
K19	K15	SURG	1	24	10/31/2008	89
K29	K15	SURG	1	24	10/31/2008	89
K31	K88	BRKR	1	24	10/31/2008	66
K31	K88	BRKR	3	24	10/31/2008	66
K33	K15	SURG	1	24	10/31/2008	89
K36	K88	SURG	1	24	10/31/2008	89
K42	K88	BRKR	2	24	10/31/2008	66
K55	K88	SURG	1	24	10/31/2008	89
K56	K15	SURG	1	24	10/31/2008	89
K56	K88	SURG	1	24	10/31/2008	89
K58	K15	SURG	1	24	10/31/2008	106
K58	K88	SURG	1	24	10/31/2008	106
K93	K15	SURG	1	24	10/31/2008	89
K93	K88	SURG	1	24	10/31/2008	89

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Data availability The datasets generated during and/or analysed during the current study are available from Abu Bakkar Siddique (adiddi@gmu.edu) on reasonable request.

Declarations

Conflict of interests The authors have no financial or proprietary interests in any material discussed in this article.

References

Albarán ES, Santos D, Salamanca LJG (2017) The "Medicus Case": Organ Trafficking Network in Kosovo (The Global Observatory of Transnational Criminal Networks No. 14). Vortex Foundation

Ambagtsheer F, Pascalev A, de Jong J, Lundin S, Ivanovski N, Codreanu N, Gunnarson M, Jankov J, Frunza M, Byström I, Bos M, Weimar W (2014) Trafficking in human beings for the purpose of

organ removal: a comprehensive literature review. Transpl Immunol 31(4):254–254. https://doi.org/10.1016/j.trim.2014.11.201
Barrat A, Barthelemy M, Pastor-Satorras R, Vespignani A (2004) The architecture of complex weighted networks. Proc Natl Acad Sci 101(11):3747–3752
Berlusconi G (2022) Come at the king, you best not miss: criminal network adaptation after law enforcement targeting of key players. Global Crime 23(1):44–64. https://doi.org/10.1080/17440572.2021.2012460
Borgatti SP, Foster PC (2003) The network paradigm in organizational research: A review and typology. J Manag 29(6):991–1013. https://doi.org/10.1016/S0149-2063(03)00087-4
Borgatti SP, Halgin DS (2011) On network theory. Org Sci 22(5):1168–1181. https://doi.org/10.1287/orsc.1100.0641
Bright DA (2015) Disrupting and dismantling dark networks: Lessons from social network analysis and law enforcement simulations. Illum Dark Netw 39:39–51
Bright D, Koskinen J, Malm A (2019) Illicit network dynamics: The formation and evolution of a drug trafficking network. J Quant Criminol 35:237–258. https://doi.org/10.1007/s10940-018-9379-8
Calderoni F (2015) Predicting organized crime leaders. Crime Prev Stud, 89–110
Carley KM (2003) "Dynamic network analysis" in dynamic social network modeling and analysis: workshop summary and papers. In: Breiger R, Carley K, Pattison P (eds) Committee on Human Factors, National Research Council, National Research Council. pp 133–145
Columb S (2015) Beneath the organ trade: A critical analysis of the organ trafficking discourse. Crime Law Soc Chang 63(1–2):21–47
Columb S (2017a) Disqualified bodies: A sociolegal analysis of the organ trade in Cairo. Egypt Law Soc Rev 51(2):282–312
Columb S (2017b) Excavating the organ trade: An empirical study of organ trading networks in Cairo. Egypt Br J Criminol 57(6):1301–1321
Columb S (2020) Trading Life: Organ Trafficking, Illicit Networks, and Exploitation. Stanford University Press
Cockburn E, Brayley H, Laycock G (2011) Exploring internal child sex trafficking networks using social network analysis. Policing. J Policy Pract 5(2):144–157
Danovitch GM, Chapman J, Capron AM, Levin A, Abbud-Filho M, Al Mousawi M, Bennett W, Budiani-Saberi D, Couser W, Dittmer I, Jha V, Lavee J, Martin D, Masri M, Naicker S, Takahara S, Tibell A, Shaheen F, Anantharaman V, Delmonico FL (2013) Organ Trafficking and Transplant Tourism: The Role of Global Professional Ethical Standards—The 2008 Declaration of Istanbul. Transplantation 95(11):1306–1312. https://doi.org/10.1097/TP.0b013e318295ee7d
Diviák T, van Nassau CS, Dijkstra JK, Snijders TA (2022) Dynamics and disruption: Structural and individual changes in two Dutch Jihadi networks after police interventions. Soc Netw 70:364–374. https://doi.org/10.1016/j.socnet.2022.04.001
Diviák T, Coutinho JA, Stivala AD (2020) A man's world? comparing the structural positions of men and women in an organized criminal network. Crime Law Soc Change 74:547–569. https://doi.org/10.1007/s10611-020-09910-5
Fraser C, Koizumi N (2017) Human Organ Trafficking: A study of change in the Egyptian kidney market 2008–2016. Transplantation 101:S13
Hughes CE, Bright DA, Chalmers J (2017) Social network analysis of Australian poly-drug trafficking networks: How do drug traffickers manage multiple illicit drugs? Social Networks 51:135–147
Frydensberg C, Ariel B, Bland M (2019) Targeting the most harmful co-offenders in denmark: A social network analysis approach. Cambridge Journal of Evidence-Based Policing 3(1):21–36
Fuhse JA (2018) Deconstructing and reconstructing social networks. The Palgrave handbook of relational sociology, 457–479
Fuhse JA, Gondal N (2022) Networks from culture: Mechanisms of tie-formation follow institutionalized rules in social fields. Social Networks. https://doi.org/10.1016/j.socnet.2021.12.005
Jafar TH (2009) Organ trafficking: Global solutions for a global problem. Am J Kidney Dis 54(6):1145–1157
Kotiswaran P (2008) Born unto brothels—Toward a legal ethnography of sex work in an Indian red-light area. Law Soc Inq 33(3):579–629
Koschade SA (2007) The internal dynamics of terrorist cells: A social network analysis of terrorist cells in an Australian context. PhD thesis, Queensland University of Technology
Lancet T (2007) Legal and illegal organ donation. Elsevier

Li MH (2021) Network data. In: Schintler LA, McNeely CL (eds) Encyclopedia of Big Data. Springer, Cham. https://doi.org/10.1007/978-3-319-32001-4_411-1
Mancuso M (2014) Not all madams have a central role: Analysis of a Nigerian sex trafficking network. Trends in Organized Crime 17(1–2):66–88
Manzano A, Monaghan M, Potrata B, Clayton M (2014) The invisible issue of organ laundering. Transplantation 98(6):600–603
McCuish EC, Bouchard M, Corrado RR (2015) The search for suitable homicide co-offenders among gang members. J Contemp Crim Justice 31(3):319–336. https://doi.org/10.1177/1043986214553375
McLean P (2016) Culture in networks. John Wiley & Sons
Newman M (2010) Networks: An introduction. Oxford University Press, Oxford, England
Papachristos AV, Hureau DM, Braga AA (2013) The corner and the crew: The influence of geography and social networks on gang violence. Am Sociol Rev 78(3):417–447. https://doi.org/10.1177/0003122413486800
Pristina BC (2013) In the name of the people. https://docplayer.net/8499076-In-the-name-of-the-people.html. Accessed Jun 2018
Sanchez R (2015) United Nations investigates claim of ISIS organ theft. *CNN*. https://www.cnn.com/2015/02/18/middleeast/isis-organ-harvesting-claim/index.html. Accessed Jun 2018
Sherman LW (2007) The power few: Experimental criminology and the reduction of harm. J Exp Criminol 3(4):299–321
Singh S (2019) How should we study relational structure? Critically comparing the epistemological positions of social network analysis and field theory. Sociology 53(4):762–778. https://doi.org/10.1177/0038038518821307
Studdert-Kennedy P (2019) Costa Rica struggling to stop repeated organ trafficking cases. InSight Crime. https://insightcrime.org/news/brief/costa-rica-organ-trafficking-cases/#:~:text=InSight%20Crime%20Analysis&text=In%202018%2C%20Costa%20Rica%20agreed,from%20living%20or%20deceased%20donors. Accessed Jun 2018
Vicsek LM, Király G, Kónya H (2016) Networks in the social sciences: Comparing actor-network theory and social network analysis. Corvinus J Sociol Soc Pol 7(2):77–102. https://doi.org/10.14267/CJSSP.2016.02.04
Wasserman S, Faust K (1994) Social network analysis: Methods and applications. Cambridge University Press, Cambridge, England
Yea S (2010) Trafficking in part (s): The commercial kidney market in a Manila slum. Phil Global Soc Pol 10(3):358–376
Zhang P, Wang T, Yan J (2021) Pagerank centrality and algorithms for weighted, directed networks with applications to world input-output tables. ArXiv Preprint ArXiv:2104.02764. Accessed Aug 2023