

Process mining of the appointment planning at the neurology department of Deventer Ziekenhuis

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Management summary

Introduction and problem description

The research takes place in Deventer Ziekenhuis at the neurology department. We did this research during the emerging COVID-19 crisis, which has resulted in various severe limitations for this research. Most importantly, there was no access to the hospital, and little access to its staff. The data set that was subject of this study is large, as it concerns no less than three full years. This gives great significance to the analysis, however, validation by the problem owners is still to be done, but was not possible at the time of the completion of this report. The neurology department, a broad spectrum of complaints are treated, but no clear insight in the appointment scheduling is in place. The department is characterized by patients that are treated within one consultation. For the same type of diagnosis, there is a great variation in the number of appointments and the time between the first two appointments. This research looks into this variation and what the quality of service of the department is.

Research goal

The goal of this research is to identify bottlenecks or further research options which will improve the efficiency of the department. Therefore, conclusions based on the given data will be given together with recommendations. Together with Deventer Ziekenhuis the following research question was established: *"How does the variation of care pathways affect the performance of the neurology department of DZ?"*

Approach

The conclusions and recommendations are established with different steps. First, we filtered the database by appointment codes. Not all appointment codes are clinical, those who are not clinical have been removed. The database concerning the appointments needed to be prepared for data visualization, we did that with Excel VBA. Literature research was done twice, once at the beginning on how to evaluate the quality of service of the department and once with regard to the recommendations. After that, the data was analyzed, first for the current performance, and after that on which patterns can be found in the data. Then a dashboard was designed with the relevant outcomes of the data analysis. In the end, we draw conclusions and give recommendations.

Conclusions

After reviewing the data we conclude that over the last three years the department has improved their quality of service. In 2018 they forecasted and planned the R-DBC's better than in 2017. The access time was also lower in 2018 than in 2017. In 2018, the access time was on average 18 days and in 2017 this was 24 days. The norm for 2018 was 21 days, so the access time was within the norm on average. The variation in time between the first two appointments per doctor was lower in 2019 than in 2018, which is a good thing. Around 22% of the patients only have one consultation at the department, whereas the most average number of appointments per diagnose is between 2 and 4 appointments. The overall conclusion is that the current database is not suited for routinely evaluation.

Recommendations

We strongly recommend to validate the research we did, because we did not have access to the hospital we could not do this. Another recommendation is to invest in a dashboard that shows the current performance. We propose that this dashboard projects the number of appointments scheduled during the week, what kind of consultations these are, what the current working stock is, the remaining R-DBC's, and the access time. Besides that, we recommend investigating the variation between patients with the same diagnosis, with a focus on the number of appointments. Also, qualitative research is proposed, with a focus on patient satisfaction.

Outlook

Due to COVID-19, interviews and joining the staff at the department were not possible. As a result, the data is almost only analyzed and not interpreted. The department has no clear goals or norms, to keep track of their performance, they should consider doing further research into the ideal norms. Also, we propose further research with regard to patient satisfaction.

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1 Introduction

In the past two decades, the potential of big data has become more and more intricate. Big data can be used to analyze problems differently than before. Problems can be solved by using this data, but this data can also be used to find problems. Here, a curiosity based and data-driven research comes into place. Data visualization can be used to find the needle in the haystack. Big data allows healthcare organizations to look into patterns and conclusions in patients' data. In this research, data analysis was conducted on primary care-related data of three consecutive years (2017, 2018, and 2019) from the neurology department of Deventer Ziekenhuis. Primary care is the care that is directly related to or provided for patients [8].

1.1 Context of the research

Section 1.1.1 describes Deventer Ziekenhuis with a short description and section 1.1.2 describes the neurology department.

1.1.1 Deventer Ziekenhuis

The research was initiated by Deventer Ziekenhuis, hereafter referred to as DZ. DZ is a regional hospital that provides care on three locations (Deventer, Raalte, and Rijssen). DZ is part of 'Samenwerkende Topklinische opleidingsZiekenhuizen' [4]. Every year DZ welcomes around 20.000 patients in their hospital and they visit around 300.000 patients in their outpatient clinics. DZ has 2380 employees (1721 FTE) and 187 medical specialists [3].

1.1.2 Neurology department

The neurology department treats diseases concerning the brain, spinal cord, nerves, and muscles. A neurologist examines complaints such as headaches, dizziness, double vision, radiating pain, sleep disturbances, epilepsy, muscle weakness, and disorders of thinking, behavior, and memory. The neurology department of DZ works together with the Isala Ziekenhuis in Zwolle. The neurology department of DZ has 8 medical specialists and 1 nurse specialist currently working [2].

1.2 Process mining

Healthcare processes are the activities that are aimed to diagnose, treat, and prevent diseases to improve the life of a patient. A big hurdle in making healthcare processes more efficient is that these processes are dynamic, complex, multidisciplinary, and mostly ad hoc, which means that in real life the decisions need to be made on the spot and per patient. Process mining, later explained, helps to improve the capabilities to meet the demand, to reduce the waiting times for patients, to improve resource productivity, and to increase the processes transparency. A goal of process mining is to streamline the healthcare processes better.

Process mining is the activity where extracting knowledge from data is done. For process mining of healthcare processes, two kinds of processes can be distinguished, namely clinical and administrative processes [10]. The main purpose of administrative systems is the registration of services that have been delivered to the patients. Clinical systems support the clinical work at a department, which is registering at a task-based level [7]. This research focuses on administrative processes. Besides the distinction regarding clinical and administrative, there is another distinction that can be made, namely between the purpose of the process mining. There are three different types, namely *discovery*, *conformance*, and *extension*. When *discovery* is the purpose, the main activity is to reproduce the observed behavior. An example of this is to describe the organization, performance, and data perspective. *Conformance* focuses on checking whether observed behavior conforms to a model. An example of this type is checking whether a certain guideline is always necessary. The last type is the *extension*, which is aimed to protect the information that is extracted from the data into a given model [7].

1.3 Problem description

The neurology department covers a broad spectrum of complaints. This research was initiated by DZ because they currently do not have a clear insight into this department. The current biggest problem for the department is that they do not have information on the access time, the time between the first two appointments, the difference (in days) between two appointments that are sequential, or the care pathways that patients have. Care pathways are the sequence of appointments with information about the diagnosis and doctors of a patient. This department has a lot of long-standing patients, but also a lot of new patients who just visit for one or a couple of times. This gives variation in the number of appointments and the time between the first two appointments. An insight into the process of new patients is missing at the moment.

1.4 Research goal

This research aims to find patterns and relevant insights into the appointments at the neurology department of DZ. The goal is to return clear documentation on the current performance and how variation caused by different diagnoses and doctors affects this performance.

1.4.1 Research questions

In consultation with DZ the following research question was established:

"How does the variation of care pathways affect the performance of the neurology department of DZ?"

To answer this research question, the following sub-questions were established:

1. *What is the current procedure for a new patient of the neurology department?*

This question looks into the current process concerning the appointments. The answer to this question can be found in section 2.1.2. During the conversation with the management of the neurology department, this question got answered.

2. *How is the neurology department performing?*

To give a better insight into the current performance a data analysis will be done. This data analysis focuses on new patients in the system until they leave the system or until the data is outside the scope. The performance will be reflected by a number of KPIs, which can be found in section 2.2.3. The answer to this research question was found in the databases given by DZ.

3. *What patterns can be found regarding the variation between diagnoses?*

This question looks into the variation in care pathways. This research question is answered in section 3.1. This section is based on looking at whether assumptions made by the management team are confirmed or denied by the databases.

4. *What patterns can be found regarding doctors' way of working?*

Every doctor has his/her specialism and way of working, this also means that this is a cause of the variation at the department. The answer can be found in section 3.2.2. This answer also based on assumptions made by the management, and whether those assumptions are supported by the databases.

5. *What are the recommendations for the neurology department?*

After analyzing the data on an aggregate level, we provide recommendations to handling the variation better, and to increase the efficiency of the neurology department. The recommendations are divided into two parts. The first part is about a design for a dashboard in order to keep track on the performance in the future. This can be found in chapter 4. This dashboard is based on the KPIs and on dashboards that are already used at DZ. The second part of this research question is answered in section 5.3. This part is based on the interpretation of the databases and on sources found online.

1.5 Data

The historical data is received from the patient registrations at DZ, from January 1st 2017 to December 31st 2019. The data is received from HiX, this is the electronic registration of patient data. The data gives information about the appointments during this time frame, for example, the date of the appointment, the type of consultation, and the diagnosis belonging to the patient. Qualitative data is accumulated through interviews with the staff of DZ and the neurology department and it implemented throughout the entire research. Eight doctors are taken into account. We choose not to translate the diagnoses, therefore they will be in Dutch. This is done because the names do not have an extra benefit in English and in this way it is best for DZ. Later in the research, a second database is added about the R-DBC's (reimbursement), spots in the raster, and access time, this data only concerns 2017 and 2018 and gives the values per week.

1.6 Scope

The scope gives the demarcation of the research. This is done to limit the size of the research. The neurology department of Deventer Ziekenhuis has three locations, these will be shortly mentioned in section 2.1, for the analysis and the interpretation of the data, this will not be taken into account. Co-assistants are not taken into account in this research, because they do not have a fixed influence on the performance of the department. Due to the time limit of the research, which is 10 weeks, the focus is on the doctors and patients, rather than on nursing. The time limit makes it also impossible to return a complete plan with implementations and integration of the recommendations. Therefore, in the future, the recommendations can be turned into new research.

2 Current situation analysis

This section gives an overview of the current situation of the neurology department of DZ. Section 2.1 gives an overview of the current process description. The section will start with addressing some overall facts, after that the registration of new patients is explained, followed by an explanation of the appointment codes and consultation types. Then the different doctors will be distinguished. In section 2.3 the current performance will be projected with the KPIs.

2.1 Process description

To get a better understanding of how the neurology department performs, first, a process description will follow. The neurology department has three different locations. In the years 2017, 2018, and 2019 93,9% of the appointments took place in Deventer, 3,2% in Raalte, and 2,8% in Rijssen. Over these three years, 73053 appointments were made in the schedule. However, not all appointments are clinical, therefore also not important. After filtering this out, 58623 appointments remain. Around 42% are for patients that have a control appointment. With 14%, the most common diagnosis was "Radiculair syndroom / HNP lumbaal-thoracaal".

2.1.1 Data aggregation

As mentioned before, 73053 appointments were stated in the database of 2017, 2018, and 2019. Not all appointment were clinical, therefore had to be removed. When a co-assistant has an appointment scheduled, it was always together with a specialist. Therefore there are always two doctors scheduled when a co-assistant is involved. This holds that for the same patient, the appointment is scheduled twice, once in the agenda of the specialist and once in the agenda of the co-assistant. All the appointments of the co-assistant were removed in this research. One of the reasons for this is that the validity of the time between the first two appointments could be in jeopardy if the appointments of the co-assistants are taken into account. To illustrate that, if the first appointment is with a co-assistant, this appointment occurs on the agenda of the co-assistant with also on the agenda of the specialist. The calculation of the time between the first two appointments used in this research will return a time between the first two appointments of zero days in this case. However, the patient only had one appointment and the time between the first two appointments is not zero.

In the database the appointment code "PATBES", "OVERLEG", and "REMIND" was used, however, this is not an appointment. "PATBES" is a meeting about the patient and when it is scheduled in the agenda of the specialist the medical file can be added to the appointment. The meeting is also most of the time with more than one doctor. "OVERLEG" is a meeting about a patient with other departments. This is also not an appointment with a patient. "REMIND" means that a specialist has to look again at the file of a specific patient. This also is not a real appointment. Most "PATBES" are scheduled with more specialists, as a result, that a patient has multiple appointments scheduled at the same time without the patient being actually at the appointment. This also returns a time between the first two appointments in the calculation. "OVERLEG" and "REMIND" do not return a time between the first two appointments of zero, but an appointment is added in the sequence which does not involve the patient. Therefore, these kinds of non-clinical appointments make the time between the first two appointments less accurate when they are left in. In this research appointment with either "PATBES", "OVERLEG", or "REMIND" were removed before analyzing the data. There are more codes that were removed, but they did not occur in high frequency, therefore not explained.

The original database contained the real names of the doctors. The 8 doctors with the most appointments over the last three years were selected along with one nurse specialist. The appointments that were not done by either these 8 doctors or the nurse specialist were put down as "Other doctors".

The last thing that we did in order to aggregate the data was making time clusters. In the original database the begin time, end time and duration were mentioned. With only beginning times, it is harder to analyze and compare these frequencies of appointments, therefore we changed the timestamps to timeslots of an hour.

2.1.2 Appointment codes

The registration of the appointments in the system is associated with an appointment code. New patients come to the neurology department after the referral of a general practitioner. Common causes of a referral are headaches, sleep disorders, hernias, and tunnel syndrome. The new patients need to fill in a questionnaire and if needed extra examinations are done before the first appointment with a neurologist. As a result, a lot of patients can be helped within one appointment.

If the complaint of the patient concerns a sleep disorder, the appointment is scheduled together with a pulmonologist. A common treatment at the neurology department is the Carpal Tunnel Syndrome (CTS), this complaint is often handled within one consultation. The codes for new patients contain NP. The code for a follow-up or control patient contains CP. In 2017 the code NP30 was often used, this was a consultation for a new patient with a duration of 30 minutes instead of NP with a duration of 20 minutes, this code is not used in 2018 and 2019. NPHNP concerns new patients with a (possible) hernia. NPTIA is about new patients with a transient ischemic attack. Every day there is a blockage in the agenda of one of the doctors for this kind of patient because these consultations are only known very last minute and have high priority. NPSLAAP concerns new patients with sleep disorders. Other important appointment

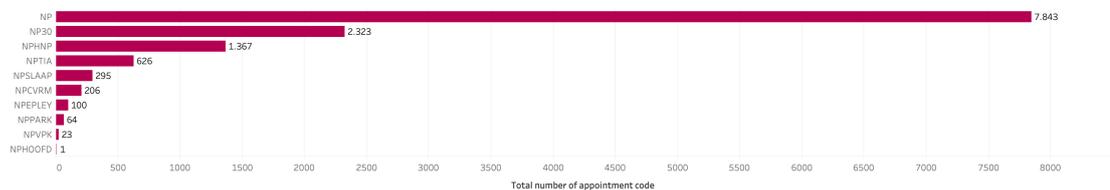


Figure 1: Graph on the total number of NP codes in the appointment system used over 2017, 2018, and 2019, src = HiX

codes are MRI, which is a magnetic resonance imaging, and TC, which is a follow-up by phone. The other appointment codes are less frequent and not included in the interpretation of the data, therefore not discussed further. In total, 115 diagnoses have been used over the last three years. However, some are more frequent than others. Table 1 shows the number of new patients, control patients, and the ratio of this on average per year. The category of other diagnoses consists of diagnoses that had a frequency that was less than 2% of the total appointments. In total 12848 new patients were documented for the last three years. The table also shows that ratio of new patients and control patients. This ratio shows the for one new patient, how many control patient appointments are scheduled for these diagnoses. For "Radiculair syndroom / HNP lumbaal-thoracaal" this means that for every new patient appointment on average 1,54 control patients are scheduled in the system.

Table 1: Number of new and control patients on average per year (over 2017, 2018, and 2019) for the most common diagnoses and ratio of new over control patients

Diagnosis (in Dutch)	New patients (NP)	Control patients (CP)	Ratio NP/CP
Radiculair syndroom / HNP lumbaal-thoracaal	742	1144	1/1,54
Morbus Parkinson	56	737	1/13,16
Radiculair syndroom / HNP cervicaal	219	360	1/1,64
Overige hoofdpijn	180	351	1/1,95
Polyneuropathie anderszins	169	323	1/1,91
Spinale stenose lumbaal	197	265	1/1,35
Epilepsie gegeneraliseerd	39	366	1/9,38
Migraine en migraine-varianten	132	256	1/1,94
Slaapstoornissen overig	179	196	1/1,09
Onbloedige beroerte	37	336	1/9,08
Nervus medianus (inclusief CTS)	125	245	1/1,96
TIA (inclusief amaurosis fugax)	202	161	1/0,80
Multiple sclerose	23	332	1/14,43
Vestibulaire aandoeningen (w.o. BPPD)	137	206	1/15,04
Other diagnoses	1846	3321	1/1,80

2.1.3 Consultation types

Besides appointment codes, an appointment also has a consultation type. Consultation type E is a first type consultation, type H is a repeat/follow-up consultation, type T are consultations by phone, type V are operational consultation and * consultation are unknown. Consultation types B and I are mentioned 8 times in the data, therefore not taken into account or discussed. The occurrence of the consultation types over the last three years can be found in figure 2.

Table 2: Occurrence of consultation types per year, src = HiX

Consultation type	2017	2018	2019
E	5909	5915	5407
H	8934	9222	8501
T	2135	3435	3874
V	928	724	739
*	994	724	944

2.1.4 Doctors

Over the last three years, DZ had eight medical specialists and one nurse specialist [2]. These doctors differ from each other, in this section an overview of the average number of appointments per year, most

common diagnoses, and appointment scheduling per doctor will be given.

Doctor 1 Doctor 1 had on average 2305 appointments per year. Most of these appointments from doctor 1 concerned "Radiculair syndroom / HNP lumbaal-thoracaal", "Slaapstoornissen overig", and "Radiculair syndroom / HNP cervicaal". Most appointments were scheduled on Monday, Wednesday, and Thursday. Also, no appointments were scheduled for Tuesday.

Doctor 2 Doctor 2 had on average 3456 appointments per year. The most common diagnoses for this doctor were "Radiculair syndroom / HNP lumbaal-thoracaal", "Radiculair syndroom / HNP cervicaal", and "Spinale stenose lumbaal". The appointments were equally scheduled over Monday, Wednesday, Thursday, and Friday. There were appointments scheduled on Tuesday, but this is way less than on the other days.

Doctor 3 Doctor 3 stopped working at DZ in August 2018 but had 1465 appointments in 2017 and 649 in 2018. Most appointments concerned "Nervus medianus (inclusief CTS)", "Verstibulaire aandoeningen (w.o. BPPD)", and "Radiculair syndroom / HNP cervicaal". Most appointments were scheduled on Tuesday in 2017 and in 2018 the appointments were only scheduled on Tuesdays.

Doctor 4 On average 2180 patients per year were seen by doctor 4. Most appointments concerned "Dystonieën (w.o. blefarospasme)", "Morbus Parkinson", and "Radiculair syndroom / HNP lumbaal-thoracaal". These appointments were mostly scheduled on Tuesdays and Wednesdays.

Doctor 5 Doctor 5 had on average 2375 appointments per year over the last three years. Doctor 5 had his/her specialty in "Morbus Parkinson", "Radiculair syndroom / HNP lumbaal-thoracaal", and "Migraine en migraine-varianten". The appointments of this doctor were equally scheduled over Monday, Tuesday, Thursday, and Friday, also no appointments were scheduled on Wednesdays.

Doctor 6 On average 2561 patients per year had an appointment with doctor 6. Most patients had the diagnosis "Radiculair syndroom / HNP lumbaal-thoracaal", "Overige hoofdpijn", and "Nervus medianus (inclusief CTS)". In 2017 the appointments were scheduled equally over Monday, Tuesday, Thursday, and Friday, in 2018 and 2019 fewer appointments were scheduled on Friday. Over the three years, Wednesday had the least appointments.

Doctor 7 Doctor 7 had in 2017 2047 appointments, in 2018 2532 appointments, and in 2019 1356 appointments. The difference between these three years is explained by that in 2017 no appointments were scheduled in January and February and in 2019 no appointments were scheduled in April and May. By far the most appointments concerned "Radiculair syndroom / HNP lumbaal-thoracaal". Besides that, also "Nervus medianus (inclusief CTS)" and "Slaapstoornissen overig". The appointments were scheduled equally over Tuesday, Wednesday, Thursday, and Friday. Almost no appointments were scheduled on Mondays.

Doctor 8 Doctor 8 started at DZ in June 2018, with 1326 appointments in 2018 and 2372 appointments in 2019. The most common diagnoses of doctor 8 were "Radiculair syndroom / HNP lumbaal-thoracaal", "Nervus medianus (inclusief CTS)", and "Polyneuropathie anderszins". The most appointments were scheduled on Tuesdays and the least on Thursdays.

Nurse specialist The nurse specialist saw an increase in the number of appointments, in 2017 760 were scheduled, in 2018 1281, and in 2019 1431 appointments. The increase is not declared by the given data. The patients that were treated by the nurse specialist had "Morbus Parkinson", "Onbloedige beroerte", or "Multiple sclerose" as most common diagnosis.

Table 3: Average number of appointments per week per doctor over 2017, 2018, and 2019, $n = 58657$ appointments, $src = HiX$

	Monday	Tuesday	Wednesday	Thursday	Friday
Doctor 1	14,9	0,5	14,0	12,4	9,0
Doctor 2	20,3	2,5	21,4	19,4	18,5
Doctor 3	1,8	23,1	1,51	0,0	0,35
Doctor 4	8,0	15,0	14,4	2,8	9,0
Doctor 5	14,6	12,5	0,6	12,7	14,7
Doctor 6	14,3	15,5	0,4	15,5	11,8
Doctor 7	0,5	11,8	14,2	13,8	10,0
Doctor 8	12,2	16,7	9,7	0,7	13,2
Nurse specialist	7,7	6,4	4,7	5,4	1,2

Table 3 gives an overview of eight doctors and the nurse specialist and on which days they work most. The values in this table are the average number of appointments per week per doctor over the last three years.

2.1.5 Reimbursement

The Dutch health care system works with DBC's, this stands for "Diagnose Behandelcombinatie", in English: Combination of diagnosis and treatment. Healthcare institutions can invoice the delivered care through DBC's to insurance companies. A DBC describes the process of a patient at the healthcare institution. This system is developed, for both healthcare institutions and insurance companies, to avoid having to invoice every single step and appointment. The invoice is based on a patient in a similar situation, and not based on the delivered care of the patient [9]. DZ works with the system that they assign a certain amount of DBC's per year to a department, this is done to optimize the care. R-DBC's are regular DBC's.

2.2 Current planning and control

This section describes the current planning and control of the neurology department. First, the hierarchical decomposition will be discussed in section 2.2.1, after that the stakeholders will be evaluated in section 2.2.2, and in section 2.2.3 the performance indicators are explained.

2.2.1 Hierarchical decomposition

The planning of the neurology department affects the performance and gives direction to the process. It will be described through the framework proposed by Hans, Van Houdenhoven, and Hulshof [2012]. This framework was proposed for healthcare planning and control, which divides it into four hierarchical levels of control and four managerial areas. This research mainly focuses on the planning of renewable resources, therefore is why only the hierarchical decomposition will be discussed.

Strategic level The strategic level focuses on structural decision making. These decisions define the organization's mission. These decisions are made on the long planning horizon and are based on forecasts and highly aggregated information [6]. Short-term changes are not easy on the strategic level, because there is not a lot of flexibility. Decisions on the strategic level concern mostly the capacity of the department, so the number of rooms, the equipment, and the staff. In this research, the number of rooms or the equipment is not investigated, but the staff is taken into account. Strategic level concerns contracting with health insurers too.

Tactical level Next to the strategic level, we have the tactical level. Here decisions are made about the execution of the processes concerning the operations, but they are made on a longer planning horizon than as the decisions on the strategic level. For example, forecasts are part of the tactical level. This forecast is based on (seasonal) demand, but also on the waiting lists. Block planning is also a tactical function, this can be found in section 3.3. Also budget allocation and treatment selection are tactical function [6]. Planning based on (seasonal) demand is part of the tactical planning. In this research, the access time is analyzed.

Operational level The operational level regards short-term decision making and has two sub-levels. The offline operational level concerns the planning that can be done in advance of operations. This level focuses on everything that is planned, therefore also here there is not much flexibility, the only flexibility is that appointments can be moved around through time. The appointment scheduling and treatment selection are examples of offline operational planning, these are important in our research because these determine for instance the time between the first two appointments. The other level is online operational planning, this level involves monitoring the process of how to react to unforeseen or unanticipated events. On this level, a lot of flexibility is required, because most decisions are short-term. Examples of operational functions are appointment scheduling, add-on scheduling of emergencies, billing, and nurse rostering [6]. This level focuses on emergencies and rush orders. During this research we left emergencies out of the scope, therefore this level will not be discussed further.

2.2.2 Stakeholders

A stakeholder has an interest in the actions and aims of an organization, they can also have the potential to influence these actions and aims. A stakeholder analysis looks from which perspective stakeholders see their relevance to a project or policy [1]. Relevant stakeholders in our research were the patients, the medical staff, and the management staff. To take all the interests into account the stakeholders need to be prioritized. This is based on two things, namely the power of the stakeholder and the interest. The combination of the two will put the stakeholder in a position in an adapted matrix of Mendelow [11], which can be seen in figure 2.

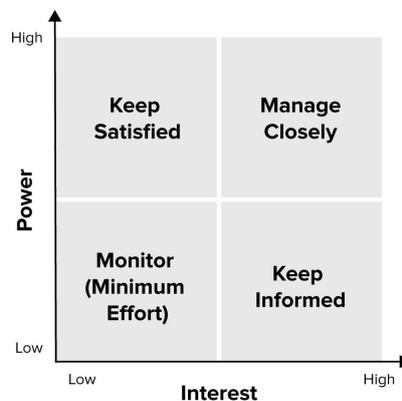


Figure 2: Adapted matrix of Mendelow [11]

Patients During our research patients do not have the power to change the research. Because they are not directly involved, only anonymized data is used. Patients are not aware of the research, but the research is in their interest, therefore their interest is low to average. This positioning returns that we should monitor the patients [11]. We monitor the patients in a way that we keep their data anonymous and that with possible outcomes and recommendations should benefit them.

Medical staff The data that is analyzed concerns the last three years, therefore the medical staff does not have the power to change the outcome of the research. However, the way the medical staff performed

during the scope influences the current analysis, therefore they are seen to have power. As the outcome of the research is about where problems are located and not how these can be solved, the interest of the doctor is low to average, because the outcome does not directly change the situation for the medical staff. This combination puts the medical staff at a spot where we should keep them satisfied [11]. We do this by listening to their preferences. However, we were not able to interview the medical staff due to the COVID-19 crisis, therefore the preferences are not taken into account.

Management staff The management staff does not have a lot of power regarding our research. On the other hand, they have a lot of interest in the research, because they want to make sure their hospital is as efficient as possible, and locating problems in the neurology department can help with that. This combination means that we should keep them informed [11]. We keep the management staff informed with this report and sharing findings during the research.

Combining the positions of the aforementioned stakeholders, none should be closely managed. This allows us to perform the research with few limitations.

2.2.3 Performance indicators

To create better insight into the current performance, key performance indicators (KPIs) should be defined. The KPIs are connected to the strategic level, the tactical level, or the operational level.

Strategic level On the strategic level, we discuss two KPIs. The first one concerns the capacity scheduled, which in this research is the number of specialists to hire, and how much they are needed at the department. The second KPI looks into the contracting with health insurers, so the number of patients that can be reimbursed. First, we look at the occupancy rate. This KPI is defined as the number of FTE (full-time equivalent) specialists hired. This KPI is defined by the number of different specialists that work during a year. The other KPI is the number of reimbursed patients. This KPI looks at the number of DBC per year and how this divided over the year. The number of appointments is here not valid, because DZ is set up a target goal of R-DBC's per department, therefore they optimize on R-DBC's instead of appointments.

Table 4: Indicators on the strategic level

Indicator	Description	Calculation method
Occupancy rate	Number of FTE specialists	Number of slots needed to provide care divided by FTE
Patients with reimbursement	Number of R-DBC's that can be reimbursed	Total reimbursed R-DBC's over a year minus the R-DBC's that already are reimbursed

The data for the first KPI should be gathered at the management of the neurology department, however in this research, we did not have this access. This KPI is interesting for the medical and management staff. For the second KPI, the data was delivered in a separate database for 2017 and 2018, including the target goal for R-DBC's and the realized R-DBC's per week. This database also included information about the spots in the raster for new consultations and the access time. This KPI is in the interests of the management staff

Tactical level On the tactical level, the KPI is the access time. Access time is defined as the number of days between the application of the general practitioner and the first appointment at DZ [12].

Table 5: Indicators on the tactical level

Indicator	Description	Calculation method
Access time	Number of days between application and first appointment	Date of first appointment minus the date of the application by the general practitioner

The data about the access time can also be found in the database about the reimbursement. This database returns the average access time per week in 2017 and 2018. The data of 2018 also has a norm of the access time. The stakeholders that have an interest in this KPI are the patients and management staff.

Operational level This paragraph gives the indicators belonging to the operational level. On the operational level, we have three KPIs. The first one is the number of cancellations per week [5]. The second KPI is about the no-shows per week, so the number of appointments where the patient did not show up for the scheduled appointment. The third KPI is the optimal deployment. We will look into the available timeslots per hour during a day to determine the utilization out of this. The last KPI is about the time between two appointments if they take place on the same day.

Table 6: Indicators on the operational level

Indicator	Description	Calculation method
Cancellation rate	Number of cancellations in a week	Total of appointment that are canceled scheduled in a certain week
No-shows	Number of appointments where the patient did not show up per week	Total of appointment with a no-show
Utilization throughout the day	Use of available timeslots	Number of scheduled appointments divided by the maximum available number of slots used in a day on average
Duration between two consecutive appointments	The time between two appointments when scheduled on the same day	The begin time of the second appointment minus the end time of the first appointment in minutes

The data of the first KPI, cancellation rate, is unknown. If the management of the neurology department wants to have a better insight into this KPI they should start documenting this. This KPI influences all three stakeholders, so the patients, medical staff, and the management staff. The second KPI concerning no-shows is also not yet documented. Here again holds that if the management wants to have a better insight they should start documenting that, this KPI also is in the interest of all three stakeholders. The third KPI is about utilization throughout the day. No clear norm or idea is set about this, right now they just fill the available slots, but that is it. So we compared the slots to the maximum number of slots on average per hour extracted from the appointment database. For a better analysis an ideal number of slots should be defined. This utilization is an important KPI for the management staff. The data of the last KPI can be extracted from the appointments database. This database contains the beginning and ending time of appointments. For this KPI the database is filtered by patients that had two appointments on the same date. This last KPI is important for the patients.

2.3 Current performance

Whereas the previous section looked into the process, this section will evaluate the performance with the key performance indicators as proposed in section 2.2.3.

2.3.1 Strategic level

On the strategic level, we look at the occupancy rate and the patients with reimbursements for the current performance.

Occupancy rate The occupancy rate is based on the number of specialists needed in order to give care to all the patients who need it. The number is set by the management of the department. Right now there are 8 specialists and 1 nurse specialist working at the neurology department. How many FTE this is, is unknown, therefore not further discussed.

Patients with reimbursement We only had data about the reimbursement over 2017 and 2018, so 2019 is disregarded with this KPI. In 2017 the management set the goal of R-DBC's at 7415. At the end of 2017 7623 R-DBC's were realized, this means that 208 R-DBC's were not reimbursed. The goal of R-DBC's were met in week 51. In 2018 the goal was set at 7504 R-DBC's, that year 7556 R-DBC's were realized. 52 R-DBC's were not reimbursed in 2018. In 2018 the goal was met in week 52. On average 143 R-DBC's was the goal in 2017 and 144 R-DBC's in 2018. In 2017 per week on average 4 R-DBC's could not be reimbursed and in 2018 this was 1.

2.3.2 Tactical level

On tactical level the access time is analyzed for an insight in the current performance.

Access time For this KPI we investigated the realized access time of 2017 and 2018, the data of 2019 was not available, and only a norm was set in 2018. The given access times are an average per week. Over 2017 the average access time was 24 days. The highest average access time was measured in week 29, this was 49 days. Whereas the lowest was measured in week 10, which was 4 days on average. In 2018 the norm was set on 21 days. The average in that year was 17 days, this means that in 2018 the access time was beneath the norm on average. The highest access time was in weeks 43, 44, and 45, all 35 days on average.

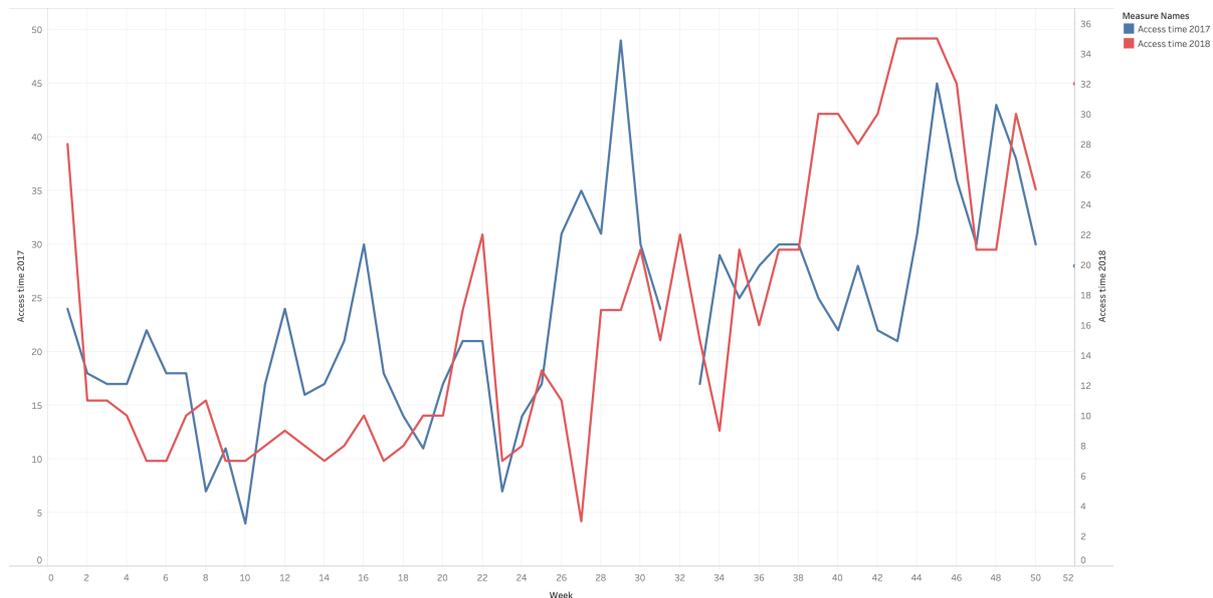


Figure 3: Access time in days on average per week for 2017 and 2018, src = HiX

In figure 3 we see the access time over time. For both years we see that the access time tends to be higher at the end of the year. A reason for this could be that the R-DBC goal was already met, but the goal

was reached in 2017 in week 51 en in 2018 in week 52. In graph 3 we see that the higher access time already starts earlier. Another reason for this could not found in this research.

2.3.3 Operational level

On operational level three KPIs say something about the current performance, namely the cancellation rate, no-shows, and the utilization throughout the day.

Cancellation rate We did not have access to data regarding cancellations, however, for a better insight into the current performance, this is a usual KPI. When the data is available, this KPI says something about how many appointments need to be rescheduled. This rescheduling can interfere with possible optimal planning. Patients that cancel can probably not be scheduled on a shorter time term, therefore the time between the first two appointments only becomes higher. This KPI is not further discussed because of the lack of data.

No-shows We did not have access to data regarding no-shows. If this data was available this KPI would look at the downtime of the system. If a patient does not show, the spot will still be reserved for him or her. This time is then useless because on such short notice another can not be rescheduled and the specialist has to wait first if the patient really does not show. This KPI is not further discussed because of the lack of data.

Utilization throughout the day This KPI looks into the utilization per timeslot during the day. First, we take a look at the distribution of the appointments scheduled during the day. Therefore, we divided the appointments into 12 timeslots based on their starting time, this returned the average number of appointments starting within that timeslot as is shown in table 7

Table 7: Average scheduled appointments per timeslot over the last three years, n = 58662, src = HiX

timeslot	Average number of appointments
Before 07:59h	0,03
Between 08:00h-08:59h	1,91
Between 09:00h-09:59h	9,29
Between 10:00h-10:59h	10,42
Between 11:00h-11:59h	10,12
Between 12:00h-12:59h	3,02
Between 13:00h-13:59h	8,25
Between 14:00h-14:59h	9,67
Between 15:00h-15:59h	8,65
Between 16:00h-16:59h	7,27
Between 17:00h-17:59h	6,19
after 18:00h	0,58

Here we see that most appointments are scheduled in the timeslot 10:00h-10:59h. There is no information about what the ideal number of appointments per hour is, therefore we calculate the utilization per timeslot with taking 10,42 appointments as the optimal number of appointments. Before 07:59h and after 18:00h will be left out for this KPI because these slots are not over the same time frame.

Table 8: Utilization per timeslot

timeslot	Utilization of timeslot
Between 08:00h-08:59h	18,3%
Between 09:00h-09:59h	89,2%
Between 10:00h-10:59h	100%
Between 11:00h-11:59h	97,1%
Between 12:00h-12:59h	29,0%
Between 13:00h-13:59h	79,2%
Between 14:00h-14:59h	92,8%
Between 15:00h-15:59h	83,0%
Between 16:00h-16:59h	69,8%
Between 17:00h-17:59h	59,4%

In this table we see the timeslot of 08:00h-08:59h and 12:00h-12:59h have low utilization. Most doctors do not start their working day at 08:00h, therefore fewer appointments are scheduled. However, in this timeslot lies potential. Whenever the department has an high waiting list, this slot can be used to lowered the list. Between 12:00h and 12:59h a lunch break is probably scheduled.

Duration between two consecutive appointments Over the last three years in total 880 patients had two appointments that were scheduled on the same day, within total 1017 consecutive appointments. Some of these appointments overlap with each other, those appointments have either the same begin time of the same end time. 61 appointments had the same starting time and 76 the same end time. The average time between the end time of the first appointment and the begin time of the second appointment was 116 minutes over the last 3 years. That the appointments were scheduled right after each other, so with 0 minutes, occurred 153 times. The most time between two consecutive appointments was 580 minutes. The second appointment was most of the time a consultation by phone or concerned a patient with a TIA if the duration was more than 400 minutes. If there is less time between two consecutive appointments most patients are more satisfied because they can wait in the hospital and do not have to come a second time. So duration of on average 116 minutes means that on average patients had to wait almost 2 hours. However the median is 40 minutes, with this in mind, the average is strongly influenced by higher duration. If we exclude consultations by phone for the second appointment the average drops to 90 minutes. If we also exclude the patients with a TIA the average drops to 66 minutes. This is 50 minutes less than the overall average. To connect this average to how the neurology department is performing a norm is needed. Right now, no norm is set, so therefore not further discussed.

3 Patterns in the data

This section looks into the patterns that can be found in the data concerning the time between the first two appointments, which is divided by the different diagnoses and appointment codes, this can be found in section 3.1, and concerning the difference between doctors, this is section 3.2. As stated before, a lot of variation is encountered in the neurology department. Next to the high amount of different diagnoses, there is a variation in the number of appointments. There is a big group of patients that only has one appointment at the neurology department, but there is also a group that is seen quite often due to chronic disease. This difference makes the variation between patients even with the same diagnosis really big.

3.1 Variation between diagnoses

This section gives an overview of the patterns that were found in the data concerning variation between diagnoses. The first pattern concerns the number of appointments and can be found in section 3.1.1. The second pattern, section 3.1.2, is about patients that have not been clearly diagnosed at their first appointment. After that, in section 3.1.3, takes a look at what patterns were found concerning the difference in time between the first two appointments per diagnosis. Then in section 3.2, the patterns that were found in the data concerning variation between doctors will be evaluated. First, in section 3.2.1, the use of appointment codes per doctor will be discussed. The patterns concerning the time between the first two appointments can be found in section 3.2.2. Section 3.3 the patterns that were found about the appointment scheduling per doctor will be addressed.

3.1.1 Number of appointments

A cause of the variation between patients is the number of appointments. First, we will discuss patients who were only at the department for one appointment. In total 2159 patients out of the 9884 new patients that entered the system had only one appointment. The most common diagnosis given for this was that it was not related to neurology, this makes sense because then there is no need for a second appointment at this department. Maybe this patient is forwarded to another department, but this lies outside the scope of this research, therefore not discussed. The other diagnoses can be found in appendix A.1.

Table 9 and table 10 both display the average number of appointments, the maximum number of appointments, the minimum number of appointments, and the number of patients diagnosed. The difference between these two tables is that table 9 is sorted by the highest number of average appointments, whereas table 10 is sorted by the highest number of diagnosed patients. The entire table can be found in appendix A.2.

Over the last three years, 202 out of the 447 patients that were diagnosed with a TIA only had one appointment. The maximum number of appointments was 12 and on average these patients had 2,11 appointments. Another diagnosis that was often seen only once was "Radiculair syndroom / HNP lumbaal-thoracaal", if we compare table 10 with the analysis of the single consultations, we find that 163 patients only had one appointment, this is a little bit less than 10% out of the total number of new patients with this diagnosis. We see that for the 10 most common diagnoses the average number of appointments is lower than all the values in table 9.

We will first take a closer look at table 9. In this table, only the diagnoses are taken into account if the diagnosis occurred at least four times. "Primair maligne neoplasma intracerebraal" had the highest number of average appointments per patient over the last three years. The average was 11,50 appointments, whereas the maximum was 32. The maximum of 32 makes the average less reliable because the median, for example, is 6. So the patient that had 32 appointments influenced the average quite a lot. If we take a look at "Morbus Parkinson" we see that 135 new patients were diagnosed over the last three years. The range of values that the number of appointments had is quite big. The average lies more closely to the minimum, therefore it is assumed that the maximum of 26 appointments is an exception. Looking at the range, "Multiple sclerose" returns even a bigger one. The difference between the average and the maximum number of appointments is here again very high. This big difference makes it hard to forecast care pathways.

Table 9: Top 10 of highest number of appointments per diagnosis on average over 2017, 2018, and 2019, src = HiX

Diagnosis	Average #appointments	Minimum #appointments	Maximum #appointments	Diagnosed patients (n)
1. Primair maligne neoplasma intracerebraal	11,5	3	32	6
2. Morbus Parkinson	8,5	1	26	135
3. Nervus Opticus	6,3	2	21	6
4. Multiple sclerose	5,8	1	35	54
5. Dystonicën (w.o. blefarospasme)	5,2	1	14	48
6. Polyneuropathie infectieus (GBS/CIDP)	5,0	1	12	7
7. Secundair maligne neoplasma intracerebraal (metastase)	4,8	1	10	10
8. Perifere zenuwen (inclusief wortels)	4,5	1	16	11
9. Postlaminectomiesyndroom	4,4	1	11	18
10. Extrapyramidaal niet Morbus Parkinson	4,4	1	17	114

Table 10: Average number of appointments for the 10 most common diagnoses over 2017, 2018, and 2019, src = HiX

Diagnosis	Average #appointments	Minimum #appointments	Maximum #appointments	Diagnosed patients (n)
1. Radiculair syndroom / HNP lumbaal-thoracaal	3,7	1	24	1694
2. Slaapstoornissen overig	2,4	1	11	470
3. Overige hoofdpijn	3,2	1	17	465
4. Radiculair syndroom / HNP cervicaal	3,1	1	18	453
5. TIA (inclusief amaurosis fugax)	2,1	1	12	447
6. Polyneuropathie anderszins	3,4	1	17	417
7. Spinale stenose lumbaal	3,6	1	12	387
8. Migraine en migraine-varianten	3,3	1	36	352
9. Vestibulaire aandoeningen (w.o. BPPD)	2,3	1	12	325
10. Nervus medainus (inclusief CTS)	2,9	1	16	293

Table 10 focuses more specifically on how often the diagnoses occurred. A remarkable thing we see is that the minimum of all the diagnoses is 1 and the average is for all between 2 and 4. Therefore these

diagnoses are better to forecast. One thing that should be said here, it is, of course, easier to forecast the average number over a higher number of observations. But again here we see that the the maximum number of appointments over the last three years is sometimes quite high in comparison with the average. The table for all the other diagnoses that occurred at least 4 time or more can be found in appendix A.2.

3.1.2 Patients without a clear diagnosis

Besides the more detailed diagnoses, a part of the patients was not diagnosed after the first appointment. Over the last three years this holds for 2110 patients. A total of 1431 patients that were not diagnosed came back for a second appointment, for 10 of them, the diagnosis changed to a more detailed one (to "onbloedige beroerte"). The different reasons for a no clear diagnosis can be found in table 11.

Table 11: Overview of patients without a clear diagnosis over the last three years, src = HiX

Diagnosis	Number of patients (n)	Number of follow-ups
Overige hoofdpijn	465	415
Geen neurologie, werkdiagnose overig	330	121
Afspraak niet gekoppeld aan diagnose	219	122
Overige aandoeningen bewegingsstelsel	166	113
Overige paroxysmale afwijkingen)	165	113
Overige plexus / perifere zenuwaand.	140	115
Overige cognitieve en geheugenstoorninssen	122	108
Pijn, niet elders classificeerbaar	114	47
Onbekend	89	44
Overige psychische stoorninssen	62	45
Overige cerebrovasculaire aandoeningen	57	46
Overige neuromusculaire aandoeningen	53	41
Geen neurologie, werkdiagnose multiple sclerose	23	21
Duizeligheid, niet elders classificeerbaar	23	16
Overige systeemaandoeningen CZS	23	20
Neurologie, niet elders classificeerbaar	21	16
Overige aandoeningen zintuigsystemen	15	11
Overige hersenzenuwen	13	8
Overige neuro-oncologie	10	9

3.1.3 time between the first two appointments

time between the first two appointments is defined as the difference (in days) between the first two appointments. The time between the first two appointments can also differ considerably between patients, this can be due to several things. time between the first two appointments can differ based on the diagnosis, but also on appointment codes. In this section we will look into how the time between the first two appointments differs between patients, here we do not take the difference as a result of different doctors into account, we will do that in section 3.2.2.

DZ was interested in whether the diagnosis often changed between the first and second appointment, in

the data we found that this happened to 453 patients. Looking at the changes in diagnoses that were made in the last three years, there is no clear conclusion. The change from TIA to that the appointment is not connected to a diagnosis occurred the most, 23 times to be precise. On average the time between these two appointments was 46 days. Besides this change, the other changes did not happen on a high occurrence, therefore this is not seen as a pattern.

The time between the first two appointments can differ quite a lot per diagnosis. This variation can be expected or unexpected. The expected variation is the time that is already set. An example of this is when a patient comes to the department for the first time and after that only needs a follow-up for control. The time frame of when this control appointment should take place is most of the time set by the doctor when he or she thinks it is necessary. The time between the first two appointments between these two kinds of appointments is then less interesting. However, this difference is only known of the record and therefore not taken into account. Unexpected variation in time between the first two appointments is due to other circumstances, such as holiday seasons, unavailable spots for appointments, and personal reasons of the patients. These circumstances are hard to find in the data, therefore there will not be an analysis of the reasons. This means that unexpected and expected variation will be analyzed the same.

The time between the first two appointments is also dependent on when the first (and/or second) appointment takes place. This can be seen in figure 4, this graph shows the average time between the first two appointments per month.

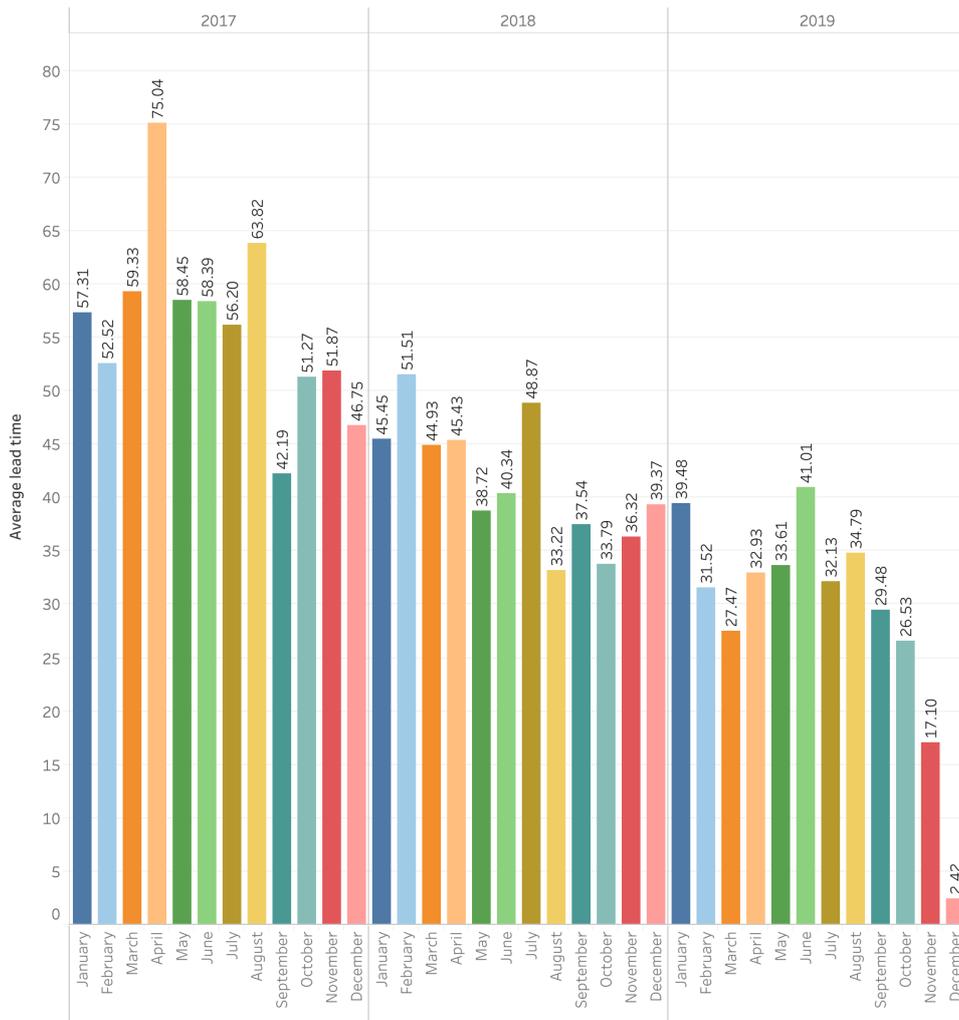


Figure 4: Average time between the first two appointments for the first appointment per month, displayed as average given when the first date took place in a particular month, src = HiX

This should be seen as when a first appointment was scheduled in January 2017, the average time between the first two appointments is 57,31 days, regardless of the type of first appointment, doctor, or diagnosis. DZ wanted to know whether the time between the first two appointments was higher during vacation periods. We see that in August 2017, July 2018 and June 2019 the time between the first two appointments is higher than the surrounding months. This could be a result of the fact that the second appointment is postponed to after the vacation, or because of other reasons.

time between the first two appointments also varies per diagnosis. The most common diagnoses that had a second appointment with average time between the first two appointments can be found in table 12. We see that the time between the first two appointments for by far the most common diagnosis at the neurology department is the second-lowest, only "Nervus medianus (inclusief CTS)" is lower. This is because CTS only needs one appointment (most of the time) after the first one because the complaint is treated within one consultation.

The second appointment can be a control appointment, but it can also be something else, such as an EMG, an MRI, or a Botox treatment. In table 13 the average time between the first two appointments between the first appointment and the EMG, Botox treatment, and MRI per year can be found.

Table 12: Average time between the first two appointments of appointments for the 10 most common diagnoses over the last three years, src = HiX

Diagnosis	Average time between the first two appointments	Total number of patients	Number of patients who had a second appointment (n)
1. Radiculair syndroom / HNP lumbaal-thoracaal	25,3	1694	1531
2. Overige hoofdpijn	41,7	465	415
3. Radiculair syndroom / HNP cervicaal	45,2	453	401
4. Polyneuropathie anderszins	37,8	417	375
5. Spinale stenose lumbaal	45,9	387	352
6. Slaapstoornissen overig	67,2	470	343
7. Migraine en migraine-varianten	52,0	352	292
8. Nervus medianus (inclusief CTS)	18,7	293	272
9. TIA (inclusief amaurosis fugax)	57,4	447	245
10. Vestibulaire aandoeningen (w.o. BPPD)	59,8	325	202

Table 13: Number of patients and average time between the first two appointments in days for MRI, EMG, and Botox, src = HiX

Second appointment	Number of patients in total (n)	2017	2018	2019
MRI	999	2,31	2,28	2,31
EMG	305	28,78	24,36	24,91
Botox	24	14,78	21,22	16,67

3.2 Variation between doctors

The doctors mainly work with their own preferences, this results in variation for somehow the same kind of patients treated by different doctors. In this section, we will look into how new patients and control patients differ per doctor.

First, we will discuss the new patients. Looking at the data, some remarkable things pop up. The first thing is that in 2017, except for doctor 6, almost no new patients were seen with a duration of 20 minutes, but all with a duration of 30 minutes. As said before this code was removed at the end of 2017.

A weekly meeting is scheduled on Friday, due to this the management assumes that most appointments are scheduled on a Friday because then the doctors are already at the hospital. If we take a look at table 3 we see that there are fewer appointments scheduled on Fridays on average. During the meeting no appointments can be scheduled, therefore over the entire day, there are fewer slots available to see patients. The only thing we see is that no doctor has a day off on Fridays.

The difference between doctors is only supported by the given data, as the real life information, such

as whether all doctors have the same abilities and whether they have specializations or not, was not available during our research.

3.2.1 Appointment codes

In this section we will look at whether there is a variation between appointment codes per doctor. The first thing we see is that Botox treatments are only done by doctors 4 and 5. Besides that, new patients with a (possible) hernia mostly go to doctor 2, 7, or 8. Consultations by phone are by far done by doctor 2, 2243 times over the last three years, whereas doctors 1, 4, and 5 had 1.192 consultations by phone on average. For doctors 3, 6, 7, and 8 this was even lower. If we take a closer look at the kind of consultation by phone of doctors, we find that they mostly connected with the "Radiculair syndroom / HNP lumbaal-thoracaal" diagnosis. On one hand, doctor 2 had the most patients with this diagnosis, but if we compare the ratio of the consultation by phone of doctor 2 with the other doctors we still find a higher ratio of doctor 2. The ratio of doctor 2 of consultation by phone in comparison with the total patients he/she had an appointment with concerned this diagnosis is 0,27; whereas the highest ratio of one of the other doctors is 0,16. As can be seen in table 14, doctor 2 has the highest ratio. Comparing it with doctors 1, 4, 5, and 7 the ratio is not that much higher. So where doctor 2 has a high ratio of consultation by phone for the diagnosis "Radiculair syndroom / HNP lumbaal-thoracaal", it balances out with for example "Slaapstoornissen overig" for doctor 1, "Morbus Parkinson" for doctor 4, and "Multiple sclerose" for doctor 5.

Table 14: Ratio of consultation by phone per doctor over the last three years, src = HiX

	Number of phone consultations	Total number of appointments (n)	ratio
Doctor 1	1127	6916	0,16/0,84
Doctor 2	2243	10581	0,21/0,79
Doctor 3	31	2114	0,01/0,99
Doctor 4	1177	6688	0,18/0,82
Doctor 5	1272	7126	0,18/0,82
Doctor 6	550	7685	0,07/0,93
Doctor 7	938	5935	0,16/0,84
Doctor 8	462	3698	0,12/0,88

3.2.2 time between the first two appointments

In this section, we take a closer look at the time between the first two appointments per doctor and how this varies. A general overview can be found in figure 5.

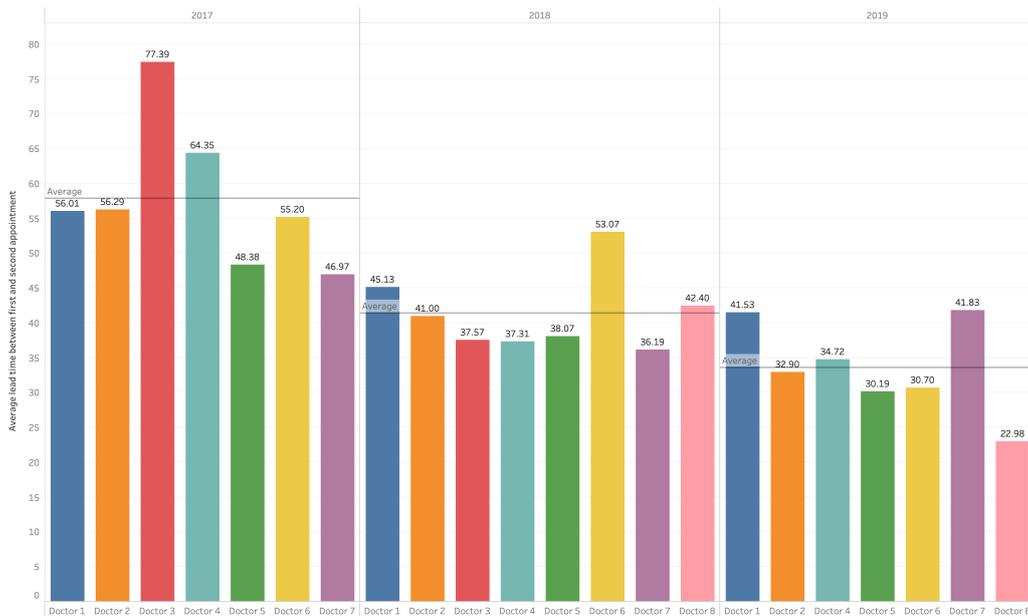


Figure 5: Average time between the first two appointments in days between the first and the second appointment per doctor over 2017, 2018, and 2019, src = HiX

We see that the overall average per doctor gets lower from 57,80 to 41,34 to 33,55 days over the last three years. To put this graph into perspective it should be compared with the number of appointments that were taken into account for the calculation of the average time between the first two appointments, this can be found in table 15. Comparing those two, we see that on one hand the average time between

Table 15: Overview of second appointments per doctor over 2017, 2018, and 2019, src = HiX

	2017	2018	2019	Total (n)
Doctor 1	553	497	264	1314
Doctor 2	566	440	345	1351
Doctor 3	185	51	0	236
Doctor 4	193	225	166	584
Doctor 5	350	369	262	981
Doctor 6	630	461	296	1387
Doctor 7	490	460	165	1115
Doctor 8	0	295	295	590
Total	3012	2866	1847	77250

the first two appointments in 2017 of doctors 3 and 4 is higher than the average, but we also see that they had less appointments. For doctor 3 we find that there are a few patients with a very high time between the first two appointments, with the maximum at 790 days. In figure 6 an overview is given of the occurrence of time between the first two appointments per doctor which exceeds 200 days.

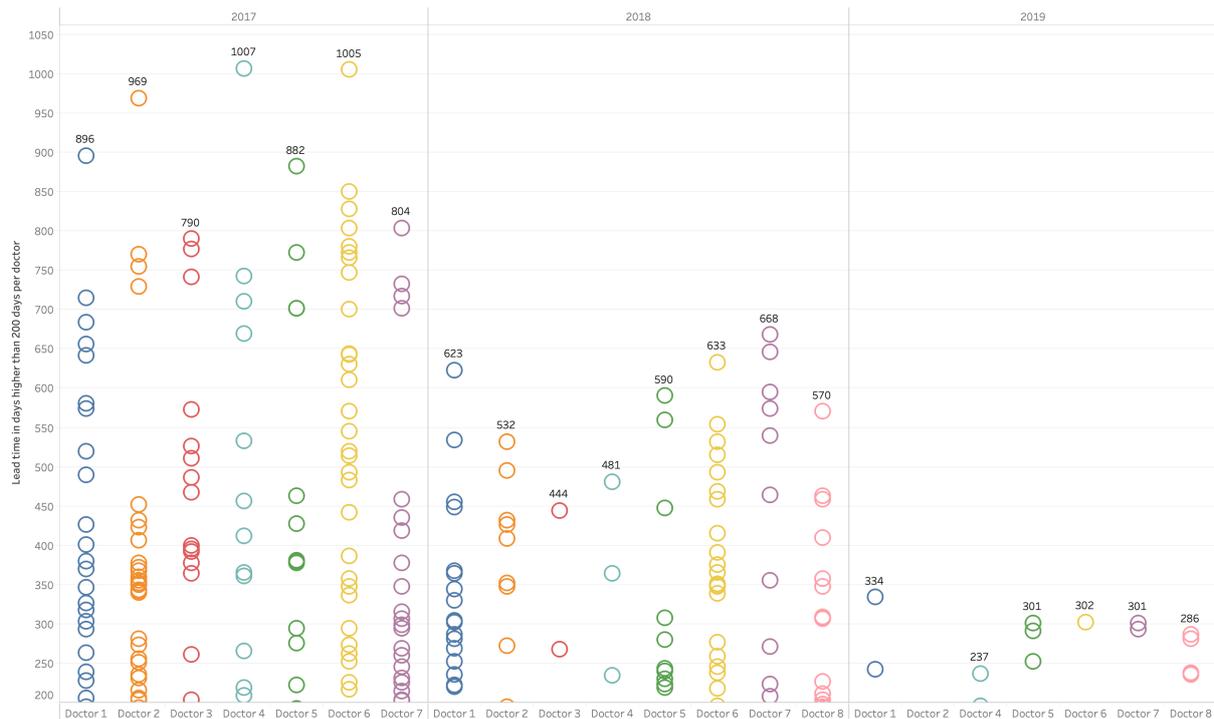


Figure 6: Occurrence of high time between the first two appointments per doctor over 2017, 2018, and 2019, $n = 246$, $\text{src} = \text{HiX}$

From this figure we see that on average the high time between the first two appointments lowers over time. In 2017 148 patients had a time between the first two appointments that was higher than 200 days, in 2018 this lowered to 84 and in 2019 this was already 14. One thing that should be mentioned here is that the database stops at the end of 2019. This means that patients with a high time between the first two appointments, more than 200 days, could be scheduled in 2020 or even later. The maximum time between the first two appointments of a first appointment scheduled in 2018 is in theory 730 days (all the days in either 2018 or 2019), for 2019 this maximum is 365 days.

In figure 4 the time between the first two appointments was given on average per month. In both figure 4 and figure 5 we see a decrease. However this decrease is not completely the same. If we compare 2017 and 2018, the time between the first two appointments per doctor lowered 28,4% on average, per month this was 19,2% lower. For 2018 and 2019, the time between the first two appointments per doctor decrease with 18,8% and per month on average by 29.7%. An explanation for this difference was not found in the data, also no explanation for this was given by the management.

The last thing that will be analyzed concerning the variation between doctors is the time between the first two appointments for control patients per doctor. Here we see that in 2017 doctor 3 also had the highest average time between the first two appointments for control patients. Whereas the highest time between the first two appointments was doctor 1, namely 1006 days. The same as in figure 4, we see that the time between the first two appointments is, on average, getting less over the three years. In 2018 more appointment slots became available as a result of a new doctor (doctor 8), this is probably one of the reasons for lower time between the first two appointments in the last two years.

3.3 Appointment scheduling

Some treatments are most of the time scheduled on the same day. This holds for CTS, these appointments were (except 4 consultations) scheduled on Tuesdays and Thursdays. HPHNP (new patients with a hernia) and CPHNP (control patients with a hernia) were mostly scheduled on Mondays, Wednesdays, and Fridays. MRIs were mostly scheduled on Mondays, Wednesdays, and Thursdays. Appointments

Table 16: Average time between the first two appointments in days for control patients between second and third appointment per doctor over 2017, 2018, and 2019, n = 732, src = HiX

	2017	2018	2019	Highest time between the first two appointments
Doctor 1	143	81	61	1006
Doctor 2	150	125	73	846
Doctor 3	190	99	n/a	850
Doctor 4	90	78	47	960
Doctor 5	117	97	47	937
Doctor 6	155	120	55	886
Doctor 7	108	83	45	818
Doctor 8	n/a	56	40	508

concerning Botox treatments were generally scheduled on Mondays and Tuesdays. The other types of appointments were approximately equally divided or were not that common to base conclusions on.

The order of appointments also influences the appointment scheduling. If we look at a new patient, most become a control patient from the second appointment. If a patient already comes in as a new patient with a (possible) hernia, the second appointment are almost always an MRI. If the patient comes in with (possible) Parkinson, the second appointment has the "super" code, which means supervision after the diagnosis is set. The second consultation of the most common diagnosis ("Radiculair syndroom / HNP lumbaal-thoracaal") an MRI is planned. Besides this, the data supports that patients with "Tremoren" have almost as often a second appointment by phone than in real life, also for "Migraine en migraine-varianten" 30% of the follow-up control appointments is by phone. 60 % of the patients with "Dystonieën (w.o. blefarospasme)" have a Botox consultation as their second appointment. For the diagnosis "Overige plexus / perifere zenuwaand.", the second consultation concerns an EMG for most patients. No further clear appointment orders can be found per diagnosis.

4 Dashboard design

In this research, we studied how the neurology department performed over the last three years. In the future, a dashboard can help with keeping track of the performance. Therefore we propose a dashboard with the most important KPIs. This dashboard can be found in figure 7. The dashboard design that we propose, contains the number of appointments scheduled for the current week. We also propose the indicator which shows how much the number of appointments has changed in comparison with last week. Besides that, the design shows the availability of the specialists that are in at the current day. Also, the reimbursements that still can be made, according to the preset goal, are projected. This is shown on the yearly and weekly basis. Patient satisfaction is taken into account in the design to check how the patients experienced their appointment. In the future, the department can choose how they want to implement patient satisfaction. This satisfaction can be projected per week or over a longer horizon. The design also reflects the consultations that are scheduled the current week. The working stock reflects the people on the waiting list, but also the patients that are already scheduled but are still waiting for their first appointment. The last part of the design we propose is a graph on the access time. We propose that this graph reflects the previous, current, and next week. It also gives the values of current and last year, next to the norm. We decided not to take the time between the first two appointments into account for the dashboard design. During the research, it became clear that this is not a priority for DZ. The values in this design are based on averages of both databases, the patient satisfaction is fictional.

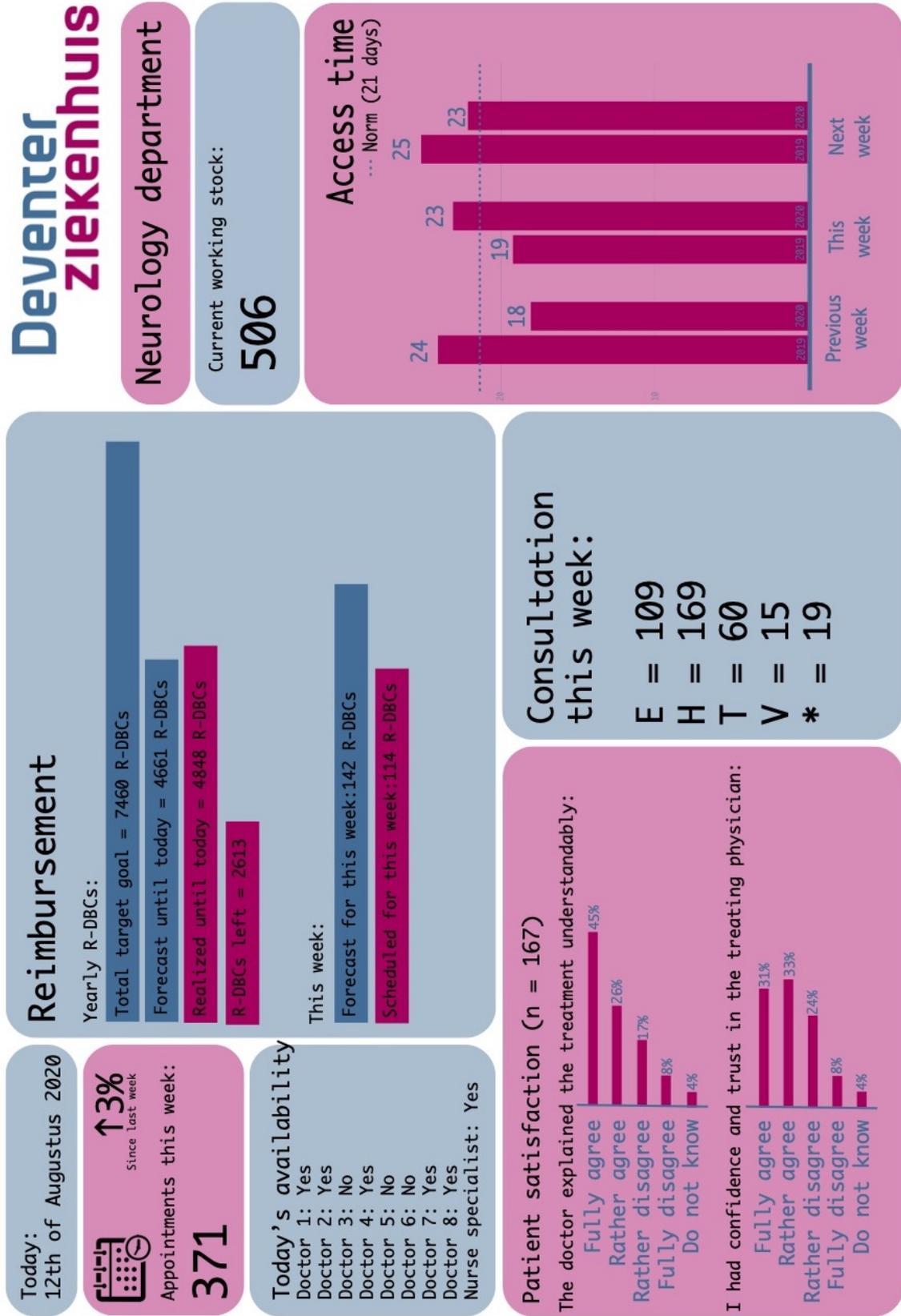


Figure 7: Dashboard design for the neurology department of DZ

5 Conclusion and recommendations

5.1 Conclusion

To answer the main research question the sub-questions will be shortly mentioned first in section 5.1.1, after that in section 5.1.2 we address the research question, and in 5.1.1 we address other conclusions of this research.

5.1.1 Sub-questions

"1. What is the current procedure for a new patients of the neurology department?" We described this process in section 2.1.2. A patient enters the system of the neurology department after a referral of the general practitioner. The patient fills in a questionnaire before the first appointment. After that, the patient is scheduled with the right specialist or together with another department.

"2. How is the neurology department performing?" This question is mostly answered in section 2, but also a bit in section 3. More R-DBC's were done than could be reimbursed. However, this surplus was in 2018 already less than in 2017. Conclusions based on those values the department performed better in 2018, they mainly scheduled and forecasted their R-DBC's better. For the access time holds that on average in 2017 this was 24 days and in 2018 17 days, this means that the access time lowered, which makes the department better performing because they strive for the lowest access time that is possible. In 2018 the access time was set at a maximum of 21 days, on average they met this norm. It becomes clear that "Radiculair syndroom / HNP lumbaal-thoracaal" is the most common diagnosis out of 115 diagnoses. We see that there is a difference between diagnoses concerning new and control patients. "Morbus Parkinson" patients, for example, mostly control patients, whereas more new patients with "TIA" are seen, than control patients. We observe a striking difference between E (first) consultations and NP codes. 12848 patients got the NP code, whereas 17231 patients got an E consultation. This can be explained by that CTS patients always (1619 times over 2017, 2018, and 2019) being seen as NP. Also, 1860 patients with an E consultation have the appointment code of SUPER, which means supervision. The highest number of appointments per month was in 2018, but the biggest difference between the month with the lowest and highest demand was in 2019. Differences between months makes forecasting and planning harder. Therefore, it is important that the differences between months are controlled rather than the differences between years.

"3. What patterns can be found regarding the variation between diagnoses?" The patterns as a result of the variation between diagnoses can be found in section 3.1. The first remarkable outcome is that around 22% of the new patients are never return in the system again. For the 10 most common diagnoses the average number of appointments is between 2 and 4 appointments, whereas the highest average is 11,50 appointments for the diagnosis "Primair maligne neoplasma intracerebraal". The average time between the first two appointments for an MRI is a little bit more than 2 days, as 333 patients on average per year needed, this is a good performance.

"4. What patterns can be found regarding doctors' way of working?" In section 3.2 this sub-questions is answered. The main outcome is the difference in the use of consultation by phone, especially for "Radiculair syndroom / HNP lumbaal-thoracaal", where doctor 2 had relatively more consultations by phone compared with the other doctors, however, this difference is not that high that it is alarming. Further, we can conclude that the difference between the time between the first two appointments of control patients, which can be seen in table 5, has the biggest variation in 2018. Luckily in 2019, we see that this variation is less.

"5. What are the recommendations for the neurology department?" The biggest recommendation for the neurology department is to look into the variation for patients with the same diagnosis. "Radiculair syndroom / HNP lumbaal-thoracaal" is diagnosed the most, but even within this diagnosis, there is a big difference in time between the first two appointments, but also in the number of appointments. Further recommendations can be found in section 5.3.

Other conclusions We concluded during the research that the time between the first two appointments is not as important to the management staff as we thought. Therefore, a focus on the access time is better. The time between the first two appointments depends heavily on what time is needed and less on the quality of service. For the management the information concerning new patients of the entire hospital is closely related to the number of E consultations, for the neurology department the number of new patients as appointment code is more reliable.

5.1.2 Research question

The research question was:

"How does the variation of care pathways affect the performance of the neurology department of DZ?"

A straight answer to this question cannot be given because further qualitative research should be done. With the limited data available on the access time we see that it improved. We can also conclude that over the last three years the department has improved the time between the first two appointments, as we can see in figure 4. Whereas the time between the first two appointments lowered over the last three years, the variation between the minimum number and the maximum number of appointments per month was biggest in 2019. Per diagnosis, there is a big difference between patients regarding the number of appointments and the time between the first two appointments. Besides that there is a variation between how doctors handle the same diagnosis, also the time between the first two appointments between doctors for control patients varies.

To answer the research question, the variation of care pathways is influencing the performance in such a way that a forecast is hard to make. For the management, the current variation makes it hard to find proper improvement points, and for the patients, their care pathways are determined by the season and the type of doctor they visit.

5.2 Discussion

In this section, the discussion of the research is addressed. Here remarks on the research are discussed. This research was conducted during the emerging COVID-19 crisis, which has resulted in various severe limitations for this research. Most importantly, there was no access to the hospital, and little access to its staff. The data set that was subject of this study is large, as it concerns no less than three full years. This gives great significance to the analysis, however, validation by the problem owners is still to be done, but was not possible at the time of the completion of this report. Another limitation of the research concerns the data. Shortly mentioned in section 2.1, but the data consisted of a lot of appointments that were not clinical and therefore not to be taken into account. Knowing that the data does not give a 100% accurate representation. To make the data more accurate, every single appointment should have been evaluated, this was not possible within the scope of this research.

The next limitation is about the information regarding the department. There was limited information online available about the neurology department of DZ and due to circumstances interviews and joining the staff at the department were not possible. As a result, the comparison between norm and reality was not always possible, because the norm was unknown and the description of the data to understand the reality was not possible.

The recommendations are mostly based on further research as the goal of this research was to return clear documentation. Therefore the recommendations are based on what was missed in this research and what should be invested to make a clear plan of recommendations to improve the performance and how this should be implemented.

5.3 Recommendations

A bottleneck in making the neurology department more efficient is the big variation in patients, mostly patients with the same diagnosis. Healthcare is most of the time ad hoc, which makes sense because no

patient is the same. With new technologies, we can focus more on customized care. Therefore, two different types of variation can be distinct, the desirable and undesirable variation. Customized care belongs to the desirable variation. The undesirable variation comes around when the care is given through a protocol. When a doctor does not take the guidelines into account than the treatment will deviate, with a probable outcome that the treatment has less result [13].

As we addressed in the discussion, it is important that this research is validated by the problem owners, mostly the management staff and partly by the medical staff.

Our first recommendation is to take a closer look at the variation at the neurology department of DZ. Further research could look into why there is such a big variation between patients with the same diagnosis. Besides that, qualitative research is proposed for the experience of patients visiting the neurology department. On one hand, research looking into the patients that only have one appointment, because from the data no proper analysis can be done. And on the other hand, a research of the most common diagnosis "Radiculair syndroom / HNP lumbaal-thoracal" is proposed, because this diagnosis has already a lot of variety, but also has enough patients, and the number of observations, to do significant research.

As can be seen in the dashboard design, we recommend taking a look into patient satisfaction. Questions such as 'The doctor explained the treatment understandably' and 'I had confidence and trust in the treating physician' can be a great start for this. Around 22% of the patients only have one treatment, therefore this is a hard group to keep track of. With a small questionnaire after their visit, the department and management gain more insight into how patients experience their visit to the department.

Our last recommendation is to invest in a better data structure. The dashboard that is proposed in chapter 4, is with the current databases almost impossible to realize. To get a better insight into the performance of the department, there needs to be a tool that makes sure all the data is filtered, sorted, and processed correctly. In this research, we did this by hand, but that is not working if the management wants to use this dashboard more often.

References

- [1] R. Brugha and Z. Varvasovszky. Stakeholder analysis: a review. *Health policy and planning*, 15(3): 239–246, 2000.
- [2] Deventer Ziekenhuis. Neurologie. <https://www.dz.nl/patient/afdelingen/neurologie>, n.d.. Accessed on 30-04-2020.
- [3] Deventer Ziekenhuis. Organisatie. <https://www.dz.nl/over-ons/organisatie#cijfers>, n.d.. Accessed on 30-04-2020.
- [4] Deventer Ziekenhuis. Over ons. <https://www.dz.nl/over-ons>, n.d.. Accessed on 30-04-2020.
- [5] E. W. Hans. Zorglogistiek / Operations Management onderzoek in Universiteit Twente's multi-disciplinaire onderzoekscentrum: CHOIR. <https://docplayer.nl/2223729-Center-for-healthcare-operations-improvement-research-www-utwente-nl-choir.html>, 2013. Accessed on 26-07-2020.
- [6] E. W. Hans, M. Van Houdenhoven, and P. J. Hulshof. A framework for healthcare planning and control. In *International Series in Operations Research and Management Science*, volume 168, pages 303–320. Springer New York LLC, 2012. doi: 10.1007/978-1-4614-1734-7{-}12.
- [7] R. S. Mans, W. M. van der Aalst, R. J. Vanwersch, and A. J. Moleman. Process mining in healthcare: Data challenges when answering frequently posed questions. In *Process Support and Knowledge Representation in Health Care*, pages 140–153. Springer, 2012.
- [8] R. S. Mans, M. Schonenberg, M. Song, W. van der Aalst, and P. Bakker. Process mining in healthcare. In *International Conference on Health Informatics (HEALTHINF'08)*, pages 118–125, 2015.
- [9] Patiëntenfederatie. Diagnose Behandelcombinatie (DBC). https://kennisbank.patiëntenfederatie.nl/app/answers/detail/a_id/202/~diagnose-behandelcombinatie-%28dbc%29, n.d. Accessed on 22-07-2020.
- [10] E. Rojas, J. Munoz-Gama, M. Sepúlveda, and D. Capurro. Process mining in healthcare: A literature review, 6 2016. ISSN 15320464.
- [11] R. Thompson. Stakeholder analysis. *Mind Tools*, 2011.
- [12] Tom van Yperen. Verbetering telt. https://www.nji.nl/nl/Download-NJi/Verbetering-telt_Prestatie-indicatoren-in-zorg-voor-jeugd_sept2012.pdf, 2012. Accessed on 22-07-2020.
- [13] van Hillegersberg - Hofmans. Gewenste en ongewenste variatie in de zorg voor kankerpatiënten. <https://www.utwente.nl/nieuws/2015/9/424887/gewenste-en-ongewenste-variantie-in-de-zorg-voor-kankerpatienten#gewenste-en-ongewenste-variantie>, 2015. Accessed on 17-06-2020.

A Appendix

A.1 Table of diagnoses with only one appointment

Table 17: Number of patients who only had one appointment per diagnosis that occurred at least 4 times (part 1), src = HiX

Diagnosis	Number of patients with only one appointment (n)
1. Geen neurologie, werkdiagnose overige	209
2. TIA (inclusief amaurosis fugax)	202
3. Radiculair sndroom / HNP lumbaal-thoracaal	163
4. Slaapstoornissen overig	127
5. Vestibulaire aandoeningen (w.o. BPPD)	123
6. Lumbago	106
7. Afspraak niet gekoppeld aan diagnose	97
8. Pseudoradiculair syndroom lumbo-sacraal	71
9. Pijn, niet elders classificeerbaar	67
10. Migraine en migraine-varianten	60
11. Pseudoradiculair syndroom cervicaal	56
12. Overige aandoeningen bewegingsstelsel	53
13. Radiculair syndroom / HNP cervicaal	52
14. Overige paroxysmale afwijkingen	52
15. Overige hoofdpijn	50
16. Mononeuritis anderszins	46
17. Onbekend	45
18. Polyneuropathie anderszins	42
19. Spinale stenose lumbaal	35
20. Epilepsie gegeneraliseerd	35
21. (vasovagale)Collaps	35
22. Nervus ulnaris	29
23. Tremoren	27
24. Overige plexus /perifere zenuwaand.	24
25. Late gevolgen trauma anderszins	22
26. Spierspanningshoofdpijn	21
27. Nervus medianus (inclusief CTS)	21
28. Onbloedige beroerte	17
29. Overige psychische stoornissen	17
30. Nervus peroneus	17
31. Whiplash injury	15

Table 18: Number of patients who only had one appointment per diagnosis that occurred at least 4 times (part 2), src = HiX

Diagnosis	Number of patients with only one appointment (n)
32. Overige cognitieve en geheugenstoornissen	14
33. Resttoestand (verworven hersenletsel)	13
34. Extrapyramidaal niet Morbus Parkinson	13
35. Narcolepsie, OSAS	13
36. Overige neuromasculaire aandoeningen	12
37. Overige cerebrovasculaire aandoeningen	11
38. Multiple sclerose	10
39. Dementie syndromen	8
40. Ruggemergaandoeningen nno	7
41. Benigne Neoplasma intracerebraal	7
42. Duizeligheid, niet elders classificeerbaar	7
43. Dystonieën (w.o. blefarospasme)	6
44. Spierziekten / myopathie	6
45. Commotio / contusio cerebri	5
46. Morbus Parkinson	5
47. Nervus V	5
48. Nervus VII	5
49. Overige hersenzenuwen	5
50. Neurologie, niet elders classificeerbaar	5
51. Slaap	5
52. Overige aandoeningen zintuigsystemen	4
53. Primair neoplasma extracerebraal (benigne of maligne)	4
54. Aandoeningen autonome zenuwstelsel	4
55. Epilepsie	4
56. Bewustzijnsstoornis, niet elders classificeerbaar	4
57. Geen neurologie, werkdiagnose poly neuropathie anderszins	4

A.2 Table of average number of appointments per diagnosis

Table 19: Average number of appointments for diagnoses that occurred 4 times or more over the last three years (part 1), src = HiX

Diagnosis	Average #appointments	Minimum #appointments	Maximum #appointments	Diagnosed patients (n)
1. Radiculair syndroom / HNP lumbaal-thoracaal	3,76	1	24	1694
2. Slaapstoornissen overig	2,40	1	11	470
3. Overige hoofdpijn	3,15	1	17	465
4. Radiculair syndroom / HNP cervicaal	3,14	1	18	453
5. TIA (inclusief amaurosis fugax)	2,11	1	12	447
6. Polyneuropathie anderszins	3,35	1	17	417
7. Spinale stenose lumbaal	3,57	1	12	387
8. Migraine en migraine-varianten	3,34	1	36	352
9. Geen neurologie, werkdiagnose overige	1,75	1	21	330
10. Vestibulaire aandoeningen (w.o. BPPD)	2,33	1	12	325
11. Nervus medainus (inclusief CTS)	2,94	1	16	293
12. Pseudoradiculair syndroom lumbosacraal	2,63	1	12	265
13. Lumbago	2,43	1	14	246
14. Afspraak niet gekoppeld aan diagnose	2,29	1	20	219
15. Nervus ulnaris	2,75	1	29	208
16. Mononeuritis anderszins	2,63	1	8	168
17. Overige aandoeningen bewegingstelsel	2,74	1	10	166
18. Overige paroxysmale afwijkingen	2,76	1	25	165
19. Pseudoradiculair syndroom cervicaal	2,43	1	13	159
20. Overige plexus / perifere zenuwaand.	2,88	1	11	140
21. Morbus Parkinson	8,48	1	26	135
22. Spierspanningshoofdpijn	2,82	1	11	131
23. Tremoren	3,39	1	18	124
24. (Vasovagale)Collaps	2,61	1	9	122

Table 20: Average number of appointments for diagnoses that occurred 4 times or more over the last three years (part 2), src = HiX

Diagnosis	Average #appointments	Minimum #appointments	Maximum #appointments	Diagnosed patients (n)
25. Overige cognitieve en geheugenstoornissen	2,77	1	13	122
26. Pijn, elders niet classificeerbaar	1,93	1	7	114
27. Extrapyramidaal niet Morbus Parkinson	4,42	1	17	114
28. Epilepsie gegeneraliseerd	2,90	1	15	102
29. Late gevolgen trauma anderszins	2,60	1	13	92
30. Onbekend	1,53	1	3	89
31. Nervus peroneus	3,06	1	11	82
32. Onbloedige beroerte	2,88	1	9	76
33. Spierziekten / myopathie	3,03	1	8	69
34. Overige psychische stoornissen	2,31	1	13	62
35. Overige cerebrovasculaire aandoeningen	2,82	1	9	57
36. Multiple sclerose	5,80	1	35	54
37. Ruggemergaandoeningen nno	3,41	1	11	54
38. Overige neuromusculaire aandoeningen	2,85	1	10	53
39. Narcolepsie, OSAS	2,67	1	11	15
40. Nervus V	3,77	1	15	48
41. Dystonieën (w.o. blefarospasme)	5,19	1	14	48
42. Spinocerebellaire aandoeningen	4,07	1	13	44
43. Dementie syndromen	3,17	1	10	42
44. Epilepsie partieel	3,97	1	15	38
45. Whiplash injury	1,97	1	6	38
46. Cervicale myelopathie	3,61	1	12	38
47. Resttoestand (verworven hersenletsel)	2,35	1	9	31
48. Aandoeningen autonome zenuwstelsel	2,79	1	6	28
49. Primair neoplasma extracerebraal (benigne of maligne)	3,44	1	7	25
50. Geen neurologie, werkdiagnose multiple sclerose	2,78	1	6	23
51. Duizeligheid, niet elders classificeerbaar	2,00	1	4	23
52. Overige systeemaandoeningen CZS	4,09	1	16	23

Table 21: Average number of appointments for diagnoses that occurred 4 times or more over the last three years (part 3), src = HiX

Diagnosis	Average #appointments	Minimum #appointments	Maximum #appointments	Diagnosed patients (n)
53. Neurologie, niet elders classificeerbaar	4,48	1	12	21
54. Commotio / contusio cerebri	2,67	1	8	21
55. Postlaminectomiesyndroom	4,44	1	11	18
56. Nervus VII	1,82	1	3	17
57. Benigne Neoplasma intracerebraal	3,63	1	19	16
58. Oogbewegingsstoornissen (Nervus III, IV, VI)	2,67	2	5	15
59. Overige aandoeningen zintuigsystemen	2,07	1	7	15
60. Overige hersenzenuwen	4,00	1	27	13
61. Specifieke neuro-infecties	2,54	1	4	13
62. Hydrocefalus	3,69	2	8	13
63. Nervus femoralis	2,25	1	4	12
64. Myasthenia gravis en myasthene syndromen	3,09	1	6	11
65. Perifere zenuwen (inclusief wortels)	4,45	1	16	11
66. Overige neuro-oncologie	4,30	1	9	10
67. Secundaire maligne neoplasma intracerebraal (metastase)	4,80	1	10	10
68. Geen neurologie, werkdiagnose TIA (incl amaurosis fugax)	2,22	1	4	9
69. Geen neurologie, werkdiagnose neopl intracerebraal	2,22	1	3	9
70. Polymyalgia reumatica / arteriitis temporalis	4,33	1	9	9
71. Letsel wervelkolom / ruggemerg	3,13	1	5	8
72. Overig letsel hoofd	2,38	1	4	8
73. Geen neurologie, werkdiagnose epilepsie gegeneraliseerd	2,14	1	4	7
74. Polyneuropathie infectieus (GBS/CIDP)	5,00	1	12	7
75. Geen neurologie, werkdiagnose polyneuropathie anderszins	2,17	1	7	6
76. Bewustzijnsstoornis, niet elders classificeerbaar	1,33	1	2	6
77. Primair maligne neoplasma intracerebraal	11,50	3	32	6

Table 22: Average number of appointments for diagnoses that occurred 4 times or more over the last three years (part 4), src = HiX

Diagnosis	Average #appoint- ments	Minimum #appoint- ments	Maximum #appoint- ments	Diagnosed patients (n)
78. Overig letsel, intoxicatie	2,17	1	3	6
79. Gehoorsstoornissen, tinnitus	3,00	2	7	6
80. Nervus Opticus	6,33	2	21	6
81. Slaap	1,00	1	1	5
82. Secundair neoplasma ex- traspinaal/epiduraal/wervelkolom (metastase)	2,80	2	5	5
83. Geen neurologie, werkdiagnose overige cognitieve en geheugenstoor- nissen	4,00	1	10	4
84. Overige deficiënties, metabool, voeding	2,00	2	2	4
85. Vitamine-deficiënties	4,25	2	8	4
86. Intracraniale bloeding (sub- / epiduraal)	4,25	1	12	4
87. Intracerebrale bloeding	2,75	1	6	4

A.3 Table of average time between the first two appointments per diagnosis

Table 23: Average time between the first two appointments in days of appointments for diagnoses that occurred 4 times or more over the last three years (part 1), src = HiX

Diagnosis	Average time between the first two appointments	Total number of patients	Number of patients who had a second appointment (n)
1. Radiculair syndroom / HNP lumbaal-thoracaal	25,25	1694	1531
2. Overige hoofdpijn	41,72	465	415
3. Radiculair syndroom / HNP cervicaal	45,15	453	401
4. Polyneuropathie anderszins	37,84	417	375
5. Spinale stenose lumbaal	45,88	387	352
6. Slaapstoornissen overig	67,24	470	343
7. Migraine en migraine-varianten	51,99	352	292
8. Nervus medianus inclusief CTS)	18,67	293	272
9. TIA (inclusief amaurosis fugax	57,35	447	245
10. Vestibulaire aandoeningen (w.o. BPPD)	59,76	325	202
11. Pseudoradiculair syndroom lumbosacraal	45,05	265	194
12. Nervus ulnaris	25,37	208	179
13. Lumbago	58,89	246	140
14. Morbus Parkinson	27,33	135	130
15. Afspraak niet gekoppeld aan diagnose	82,73	219	122
16. Mononeuritis anderszins	53,64	168	122
17. Geen neurologie, werkdiagnose overige	99,55	330	121
18. Overige plexus / perifere zenuwaand.	40,35	140	116
19. Overige paroxysmale afwijkingen	55,38	165	113
20. Overige aandoeningen bewegingstelsel	66,66	166	113
21. Spierspanningshoofdpijn	39,85	131	110
22. Overige cognitieve en geheugenstoornissen	60,79	122	108
23. Pseudoradiculair syndroom cervicaal	33,68	159	103

Table 24: Average time between the first two appointments in days of appointments for diagnoses that occurred 4 times or more over the last three years (part 2), src = HiX

Diagnosis	Average time between the first two appointments	Total number of patients	Number of patients who had a second appointment (n)
24. Extrapyramidaal niet Morbus Parkinson	45,05	114	101
25. Tremoren	47,60	124	97
26. (vasovagale)Collaps	40,31	122	87
27. Late gevolgen trauma anderszins	36,06	92	70
28. Epilepsie gegeneraliseerd	121,79	102	67
29. Nervus peroneus	43,57	82	65
30. Spierziekten / myopathie	38,94	69	63
31. Onbloedige beroerte	76,22	76	59
32. Pijn, niet elders classificeerbaar	106,62	114	47
33. Ruggemergaandoeningen nno	49,36	54	47
34. Overige cerebrovasculaire aandoeningen	72,96	57	46
35. Overige psychische stoornissen	59,56	62	45
36. Onbekend	68,18	89	44
37. Multiple sclerose	45,61	54	44
38. Nervus V	42,56	48	43
39. Spinocerebellaire aandoeningen	43,02	44	42
40. Dystonieën (w.o. blefarospasme)	25,64	48	42
41. Overige neuromasculaire aandoeningen	37,66	53	41
42. Narcolepsie, OSAS	52,28	49	36
43. Cervicale myelopathie	33,80	38	35
44. Epilepsie partieel	77,62	38	34
45. Dementie syndromen	47,68	42	34
46. Aandoeningen autonome zenuwstelsel	27,88	28	24
47. Whiplash injury	49,00	38	23
48. Geen neurologie, werkdiagnose multiple sclerose	46,00	23	21
49. Primair neoplasma extracerebraal (benigne of maligne)	62,48	25	21
50. Overige systeemaandoeningen CZS	38,85	23	20
51. Resttoestand (verworven hersenletsel)	135,38	31	18

Table 25: Average time between the first two appointments in days of appointments for diagnoses that occurred 4 times or more over the last three years (part 3), src = HiX

Diagnosis	Average time between the first two appointments	Total number of patients	Number of patients who had a second appointment (n)
52. Neurologie, nier elders classificeerbaar	41,88	21	16
53. Duizeligheid, nier elders classificeerbaar	34,88	23	16
54. Commotio / contusio cerebri	35,38	21	16
55. Postlaminectomiesyndroom	41,19	18	16
56. Oogbewegingsstoornissen (Nervus III, IV, VI)	51,47	15	15
57. Hydrocefalus	45,15	13	13
58. Nervus VII	88,42	17	12
59. Specifieke neuro-infecties	26,67	13	12
60. Overige aandoeningen zintuigsystemen	37,73	15	11
61. Myasthenia gravis en myasthenesyndromen	25,70	11	10
62. Perifere zenuwen (inclusief wortels)	31,60	11	10
63. Nervus femoralis	37,67	12	9
64. Overige neuro-oncologie	52,78	10	9
65. Benigne Neoplasma intracerebraal	116,67	16	9
66. Secundair maligne neoplasma intracerebraal (metastase)	54,11	10	9
67. Geen neurologie, werkdiagnose neopl intracerebraal	28,13	9	8
68. Overige hersenzenuwen	30,25	13	8
69. Geen neurologie, werkdiagnose TIA (incl amaurosis fugax)	13,43	9	7
70. Polymyalgia reumatica / arteriitis temporalis	13,00	9	7
71. Letsel wervelkolom / ruggemerg	127,71	8	7
72. Geen neurologie, werkdiagnose epilepsie gegeneraliseerd	25,67	7	6
73. Polyneuropathie infectieus (GBS / CIDP)	32,00	7	6
74. Primair maligne neoplasma intracerebraal	15,50	6	6
75. Overig letsel hoofd	148,17	8	6

Table 26: Average time between the first two appointments in days of appointments for diagnoses that occurred 4 times or more over the last three years (part 4), src = HiX

Diagnosis	Average time between the first two appointments	Total number of patients	Number of patients who had a second appointment (n)
76. Gehoorsstoornissen, tinnitus	67,67	6	6
77. Nervus Opticus	31,17	6	6
78. Secundair neoplasma extraspinaal/epodiraal/wervelkolom (metastase)	6,80	5	5
79. Overig letsel, intoxicatie	123,80	6	5
80. Overige deficiënties, metabool, voeding	46,50	4	4
81. Vitamine-deficiënties	66,75	4	4
82. Geen neurologie, werkdiagnose overige cognitieve en geheugenstoornissen	36,67	4	4
83. Intracerebrale bloeding	19,33	4	3
84. Geen neuropogie, werkdiagnose polyneuropathie anderszins	16,00	6	2
85. Bewustzijnsstoornis, niet elders classificeerbaar	54,00	6	2
86. Intracraniële bloeding (sub- / epiduraal)	22,50	4	2

A.4 Appointment codes taken into account

The following appointments codes have been taken into account with this research:

- Botox
- CP
- CPHNP
- CPPIJN
- CPVP
- CTS
- CTSCOMBI
- DZP
- EMG
- HOO
- HOO
- HOOCP
- HOOTEL
- MDO
- MRI
- NACO
- NECHI
- NP
- NP30
- NPCVRM
- NPEPLEY
- NPHNP
- NPHOOFD
- NPPARK
- NPSLAAP
- NPTIA
- NPVPK
- SP
- SUPER
- TC
- TC-N
- TTT
- UIT
- UITSLTTT