Identification of surgeon–individual treatment profiles to support the provision of an optimum treatment service for cataract patients

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Abstract One objective of ophthalmological departments is the optimization of patient treatment services. A strategy for optimization is the identification of individual potential for advanced training of surgeons based on their daily working results. The objective of this feasibility study was the presentation and evaluation of a strategy for the computation of surgeon–individual treatment profiles (SiTPs). We observed experienced surgeons during their standard daily performance of cataract procedures in the Ophthalmological Department of the University Medical Center Leipzig, Germany. One hundred five cases of cataract procedures were measured as Surgical Process Models (SPMs) with a detailed-to-the-second resolution. The procedures were performed by three different surgeons during their daily work. Subsequently, SiTPs were computed and analyzed from the SPMs as statistical ‘mean’ treatment strategies for each of the surgeons. The feasibility study demonstrated that it is possible to identify differences in surgeon–individual treatment profiles beyond the resolution of cut–suture times. Surgeon–individual workflows, activity frequencies and average performance durations of surgical activities during cataract procedures were analyzed. Highly significant ($p < 0.001$) workflow differences were

found between the treatment profiles of the three surgeons. Conclusively, the generation of SiTPs is a convenient strategy to identify surgeon–individual training potentials in cataract surgery. Concrete recommendations for further education can be derived from the profiles.

Keywords Education · Surgical procedures, operative · Ophthalmology · Process assessment (health care) · Workflow · Surgical process model

Introduction

The performance of surgical procedures is a complex interaction of manual skills and the experience that surgeons gather in the course of their professional life [1, 2]. The mediation of this accumulated knowledge to junior surgeons usually ensues by means of oral information, a one to one observation of the senior surgeons by the residents with subsequent practice, or other ‘knowledge stores’, such as clinical guidelines [3, 4] or dedicated literature and videos for surgical education.

It is the objective of each clinic to ensure not only an optimal, but also a homogenous, treatment service for every patient. However, due to patient-specific characteristics, different techniques favored by different seniors, to varying preferences and the availability of technical resources to support the surgical task, a variation of surgical procedure courses results. To achieve a homogenous success of treatment, it is an option to minimize the variability in treatment service caused by different surgical preferences. With relation to the individual skill and experience of the surgeons, it is necessary to identify the individual potential for improvement of their surgical

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abilities and a subsequent targeted support with the help of advanced surgical training.

The goal of the presented feasibility study was the presentation of a method and its evaluation for the computation of the individual promotion potential for surgeons in their working life by advanced training. In the course of the study, the surgical processes of 105 cataract procedures that were performed by three different surgeons were measured and analyzed. The promotion potential for each of the three surgeons was investigated and identified. The objective of the feasibility study was to answer the questions: (1) ‘How can surgeon–individual treatment service can be assessed?’, (2) ‘How can a statistically averaged surgeon–individual treatment profile (SiTP) be identified?’ and (3) ‘How can these SiTPs be used to derive advanced training strategies for the surgeon?’

The major focus of publications on the education and the training of cataract surgery was on the design and the evaluation of training programs for residents, such as the training of residents by a virtual mentor system [5], the training of complication management [6], the impact of the residents’ curriculum design on complication rates [7] or the use of models to teach residents surgical work steps in eye surgery [8, 9]. Furthermore, a number of works have focused on the objective assessment of surgical skills with advanced methods [10–12] or on data acquisition strategies in ophthalmology training [13, 14].

However, none of these works have used explicitly measured surgical processes to assess and support the education and training and to achieve detailed improvement results. The explicit measuring and modeling of the surgical processes is a relatively new research topic. So far, the application scenarios for surgical process models have mainly been the optimization of surgical treatment strategies [15] by innovative computer-assisted technologies, the comparison of different intraoperative treatment strategies [16], the evaluation of surgical mistakes [17] and the evaluation of the application of surgical tools and devices [18] or the surgical assist systems [19]. Furthermore, the approaches feature early engineering developments for the control of semi-automated surgical tasks [20], as well as process engineering [21].

In the associated literature, there is only a very limited number of approaches that explicitly deal with the acquisition and modeling of surgical processes. MacKenzie

et al. [22] presented a hierarchically organized model of a laparoscopic fundoplication procedure according to Nissen and Jannin et al. who described a method of modeling supratentorial tumor removals in the area of neurosurgery [23, 24]. However, neither of these two considered the identification of surgical treatment profiles.

We present our feasibility study along with the measurement method that was used to model the surgical treatments and the strategy of computing surgeon–individual treatment profiles. To our best knowledge, a comparable approach is not available in the appertaining literature. Therefore, we believe that this work represents an important contribution to evidence-based surgery.

Methods and materials

Patient sample and participating surgeons

In the course of the presented study, 105 cataract procedures were measured on a detailed-to-the-second work step level. All procedures were performed by experienced surgeons in their daily routine. The assignment of the patients to the respective surgeons was performed by an assistant medical director during the entry examination under exclusively clinical aspects with regard to the anticipated complications during the intervention and the health-related general condition of the patients. The decision concerning in- or outpatient intervention was made on the basis of the clinical guidelines of the German Ophthalmologic Society [25]. Two surgeons (nos. 1 and 2) performed outpatient procedures, while the third surgeon (no. 3) performed inpatient procedures. A further selection of patients, for instance with regard to age, gender or severity of affliction, did not take place, as this was irrelevant to demonstrate the applicability of the method. Table 1 shows the patient characteristics.

Measurement of surgical processes

The computation of the SiTP was a multi-stage approach comprising definitions, measurements and database computations (cp. Fig. 1, left-hand side). An overview of relevant terms used to explain these methods is presented in Table 2. The computation of SiTPs is based on a detailed

Table 1 Patient characteristics for the study

	Surgeon no. 1	Surgeon no. 2	Surgeon no. 3
No. of cases	36	18	51
Mean patient age	70.1±9.6	63.5±13.3	73.7±7.8
Sex (m/f)	14/22	9/9	22/29
Treated eye (right/left)	18/18	6/12	29/22

Fig. 1 Stages for the measurement, computation, and analysis of surgeon–individual treatment profiles (SiTP, left-hand side) and principle of the data representation in the individual Surgical Process Model (iSPM, right-hand side)

measurement of surgical activities ([26], Fig. 1, right-hand side): for every single surgical work step relevant data needs to be collected. This data encompasses information on what is being done, who performs the work step, whereby the work step is performed (meaning which instrument is being used), where at the patient's body the work step is carried out and when it is performed. The collection of all surgical activities that were measured during the treatment of one patient is termed (patient-) individual Surgical Process Model (iSPM).

At the beginning of the measurement, the clinical nomenclature needs to be defined. It comprises the names for the surgical phases of the procedure type, the surgical instruments and appliances needed, and the anatomical and pathological structures affected. This was performed jointly by a trained medical observer and an experienced surgeon from the department.

The terms of the clinical nomenclature were used to configure the measurement software, the Surgical Workflow Editor [26, 27]. The Surgical Workflow Editor software was used by an observer to measure iSPMs (cp. Fig. 2). It is able to describe the Surgical Process in detail and to the split second. During the actual intervention, the observer 'translates' the observed work steps with the help of the software into a machine-readable format. The start of each beginning interventional phase is tagged and the data concerning *who*, *what*, *whereby* and *where* is being collected (cp. Table 3). The information concerning the

when—the temporal information concerning the starting point and the breakpoint—is gathered automatically by the software.

All cataract procedures of the feasibility study were recorded by a trained medical student as observer. The observer had to complete a substantial training program before he started taking measurements. This program encompassed the dealing with the software and with the information concerning the procedure itself, such as the involved terms of the nomenclature. During data acquisition, the observer was present in the operating room during the actual intervention and operated the software on a touch screen tablet PC. The so recorded iSPMs were stored on the tablet PCs in machine-readable eXtensible Markup Language (XML) format.

Generation of surgeon–individual treatment profiles and statistical analysis

After the completion of the data acquisition, the iSPMs were transferred into a database for further processing. The activities in the iSPMs were grouped according their association to one of the surgical phases (cp. Table 4). Subsequently, a generic Surgical Process Model was computed for each of the surgeons and each of the surgical phases as surgeon–individual treatment profile. This gSPM contained the number and the average performance times of each activity and a probability for the following surgical

Table 2 Terms and definitions related to the method of measuring surgeon–individual treatment profiles

Term	Definition
Surgical Process (SP)	Surgical procedure, performed at one specific patient
Surgical Process Model (SPM)	General term for a computer model of a surgical procedure course
Activity	Representation of a surgical work step in the Surgical Process Model
Individual Surgical Process Model (iSPM)	Computer model of a surgical procedure course
Generic Surgical Process Model (gSPM)	Statistical averaged computer model of multiple surgical procedure courses
Surgeon–individual treatment profile (SiTP)	gSPM that was computed for a number of patients that were treated by the same surgeon

Fig. 2 Screenshot of the tool kit for data acquisition: the Surgical Workflow Editor

activity. Finally, the gSPMs were filtered to delete infrequently occurring activities. The strategy has been described more specifically in Neumuth et al. [16].

To assess the differences between the SiTPs of the three surgeons, we calculated means and standard deviations for the occurrence number and the mean duration of each activity as well as for the probabilities. A statistical analysis using Bonferroni tests with a significance level of $\alpha=0.05$ was performed with the help of the statistics software SPSS [28] to check the means for statistical significance.

Results

The cut–suture times showed averaged time spans of 00:23:01±00:11:59 for surgeon no. 1, 00:30:03±00:20:57 for surgeon no. 2 and 00:16:01±00:04:39 for surgeon no. 3

Table 3 Examples of activity descriptions for surgical work steps

	Example activity 1	Example activity 2
Who	Surgeon with right hand	Surgeon with right hand
What	Hydrodissection	Wash
Whereby	Sauter cannula	Sprinkler cannula
Where	Cortex	Conjunctiva
When	00:05:30–00:06:10	00:02:30–00:02:40

(cp. Table 5). The surgical core phase following the conclusion of the preparation, until the end of the Healon® removal, was 00:15:17±00:12:20 for surgeon no. 1, 00:22:17±00:21:54 for surgeon no. 2 and 00:09:50±00:03:22 for surgeon no. 3. The differences were not statistically significant, with the exception of the difference between surgeon nos. 2 and 3 ($p<0.001$).

For the surgical core phases, highly significant differences ($p<0.001$) were determined; for the phase ‘Opening of the lens bag by rhexis cannula’, for instance, for the surgeon nos. 1 and 3, as well as for nos. 2 and 3. The differences in duration of the ‘Cataract removal’ phase were highly significant ($p<0.001$) concerning surgeon nos. 2 and 3, but only on a low significance level concerning surgeon

Table 4 Interventional core phases and their definitions

Phase	Definition
Opening of the lens bag by rhexis cannula	From first paracentesis until end of material excision
Cataract removal	Form hydrodissection until end of irrigation/aspiration of lens cortex
Posterior chamber intraocular lens implantation (PC-IOL)	From incision widening until beginning of irrigation/aspiration of Healon®
Removal of Healon®	Irrigation/aspiration of Healon® from anterior chamber

Table 5 Cut-suture times and durations of the interventional phases (in hours/minutes/seconds and with mean±standard deviation)

mean±SD	Surgeon no. 1	Surgeon no. 2	Surgeon no. 3	Between subject effects	p values		
					nos. 1 and 2	nos. 1 and 3	nos. 2 and 3
Cut-suture time	00:23:01±00:11:59	00:30:03±00:20:57	00:16:01±00:04:39	$F=12.4, p<0.001$	$p>0.05$	$p=0.005$	$p<0.001$
Duration from begin of Opening the lens bag until end of removal of Healon®	00:15:17±00:12:20	00:22:17±00:21:54	00:09:50±00:03:22	$F=8.4, p<0.001$	$p>0.05$	$p>0.05$	$p<0.001$
Opening of the lens bag by rhexis cannula	00:02:44±00:01:08	00:02:57±00:01:18	00:01:28±00:00:28	$F=26.6, p<0.001$	$p>0.05$	$p<0.001$	$p<0.001$
Cataract removal	00:09:34±00:10:29	00:11:50±00:08:41	00:05:42±00:02:24	$F=9.5, p<0.001$	$p=0.05$	$p>0.05$	$p<0.001$
Posterior chamber intraocular lens implantation	00:01:02±00:01:17	00:00:50±00:00:27	00:00:42±00:00:29	$F=1.5, p>0.05$	$p>0.05$	$p>0.05$	$p>0.05$
Removal of Healon®	00:01:10±00:00:42	00:02:45±00:03:51	00:01:37±00:01:18	$F=4.1, p=0.02$	$p=0.02$	$p>0.05$	$p>0.05$

nos. 1 and 2 ($p=0.05$). The implantation of the lens showed no significant differences between the surgeons, while the removal of Healon® again showed a difference between surgeon nos. 1 and 2, but again on a low significance level ($p=0.02$).

Figure 3 shows the individual progression course of the Surgical Process for each of the three surgeons for the interventional phase ‘Opening of the lens bag by rhexis cannula’. For a higher lucidity, all activity sequences occurring with a probability of less than 10% for all three surgeons were filtered. For the same reason, activity sequences with a probability of occurrence of more than 40% for all three surgeons were highlighted as main path by bold lines. For activities thus highlighted, the durations of the work steps have been computed exemplarily in Table 5.

Table 6 shows the average number of occurrences of a surgical activity during the phase and its average cumulated execution time. It turned out that the activity ‘Paracentesis with right hand’ was performed significantly more often by surgeon nos. 3 ($p<0.001$) and 2 ($p<0.001$) than by surgeon no. 1. However, the differences in averaged total execution times were not statistically significant.

The number of the occurrences of activity ‘Capsulorhexis with right hand’, on the other hand, was not significantly different; while the averaged cumulated durations were 00:01:15±00:00:24 (surgeon no. 1), 00:01:03±00:00:23 (surgeon no. 2) and 00:00:34±00:00:11 (surgeon no. 3) and therefore significantly different between surgeon nos. 1 and 3 and nos. 2 and 3, respectively ($p<0.001$). The utilization of the different surgical instruments, micro spatula and colibri tweezers to hold the Bulbus oculi, by surgeon no. 3 is also visible in the analysis’ results.

The probability of sequence for the core activities of the surgical workflow and the respective differences in the SiTPs are represented in Table 7 and Fig. 3. While most of the activity sequences in the SiTPs were not highly significantly different, the probability for the occurrence of the sequence ‘Paracentesis with right hand’ to ‘Injection of Healon®’ was highly significant for surgeon nos. 1 and 3 on the one hand ($p<0.001$), and surgeon nos. 2 and 3 on the other ($p<0.004$). The performance of both-handed paracenteses by surgeon nos. 1 and 2 is represented in the results as statistically significant differences in the SPMs compared to the surgeon no. 3.

Discussion

The identification of surgeon–individual treatment profiles supports the provision of an optimum treatment service of ophthalmological departments. While the performance of a

Fig. 3 Visualization of the surgeon-individual treatment profiles (SiTPs) as generic Surgical Process Models of the three surgeons for the intervention phase ‘Opening of the lens bag by rhexis cannula’.

The graph shows the most frequently measured activities. The probability of on activity following another one is indicated as percentage for each surgeon with the labels on the edges

complete homogeneous treatment service is not possible due to patient-specific characteristics, the ophthalmological department can promote to come close to this objective by an advanced training of their surgical staff members for frequently occurring treatments, such as cataract procedures. We demonstrated with our feasibility study that it possible to measure and compute SiTPs. Based on this, options for individual advanced training can be identified for each surgeon.

The results of the example phase demonstrated that it is possible to measure detailed quantitative information concerning the ascertainable criteria frequency, duration and

sequence of surgical activities. With the help of the individual and generic Surgical Process Models as used in this work, treatment profiles could be derived for each surgeon.

As was shown by means of the example of the interventional phases, a selective appraisal of different time spans is possible. For instance, the differences in cut-suture times ($p < 0.001$) and in the overall durations of the single core phases ($p = 0.001$) from surgeon nos. 1 to 2 and 3 were highly significant. A further investigation has shown that these differences are mainly due to the different time spans of the phases ‘Opening of the lens bag by rhexis cannula’ ($p < 0.001$) and ‘Cataract removal’ ($p < 0.002$).

Table 6 Average performance frequencies of surgical activities and average total performance times for each surgeon

ID	Activity	Surgeon no. 1			Surgeon no. 2			Surgeon no. 3			p values		
		nos. 1 and 2	nos. 1 and 3	nos. 2 and 3	nos. 1 and 2	nos. 1 and 3	nos. 2 and 3	nos. 1 and 2	nos. 1 and 3	nos. 2 and 3	nos. 1 and 2	nos. 1 and 3	nos. 2 and 3
1	Right hand Paracentesis Paracentesis knife Cornea	0.53±0.51	0.89±0.32	1.00±0.00	p=0.001	p<0.001	p>0.05	00:00:17±00:00:30	00:00:10±00:00:08	00:00:06±00:00:01	p>0.05	p=0.01	p>0.05
2	Right hand Inject Healon®	1.17±0.45	1.50±0.92	1.04±0.34	p>0.05	p>0.05	p=0.005	00:00:06±00:00:02	00:00:10±00:00:05	00:00:04±00:00:01	p<0.001	p=0.008	p<0.001
3	Chamber ant Right hand Capsulorhexis Rhesis cannula Capsulolentis	1.11±0.52	1.28±0.83	1.02±0.24	p>0.05	p>0.05	p>0.05	00:01:15±00:00:24	00:01:03±00:00:23	00:00:34±00:00:11	p>0.05	p<0.001	p<0.001
4	Right hand Cut Lancet clear cut Cornea	1.03±0.17	1.00±0.00	1.02±0.24	p>0.05	p>0.05	p>0.05	00:00:05±00:00:01	00:00:04±00:00:01	00:00:03±00:00:01	p>0.05	p<0.001	p>0.05
5	Right hand Excision material Utrata's tweezers Capsulolentis	1.14±0.35	1.06±0.24	1.18±0.43	p>0.05	p>0.05	p>0.05	00:00:06±00:00:04	00:00:07±00:00:03	00:00:05±00:00:04	p>0.05	p>0.05	p>0.05
6	Right hand Inject Vision blue®	0.17±0.38	0.44±0.62	0.00±0.00	p=0.01	p>0.05	p<0.001	00:00:06±00:00:02	00:00:07±00:00:03	n.a.	p>0.05	-	-
7	Chamber ant Right hand Irrigate Sauter cannula	0.22±0.59	0.33±0.49	0.04±0.28	p>0.05	p>0.05	p>0.05	00:00:20±00:00:05	00:00:15±00:00:07	00:00:16±00:00:00	p>0.05	p>0.05	p>0.05
8	Chamber ant Both hands Paracentesis Paracentesis knife Cornea	0.47±0.51	0.11±0.32	0.00±0.00	p=0.001	p<0.001	p>0.05	00:00:13±00:00:20	00:00:08±00:00:01	n.a.	p>0.05	-	-
9	Left hand Hold Colibri tweezers	1.42±0.69	1.83±1.15	0.27±0.49	p>0.05	p<0.001	p<0.001	00:01:42±00:00:29	00:01:48±00:00:52	00:00:37±00:00:21	p>0.05	p<0.001	p<0.001
10	Bulbus oculi Left hand Hold Micro spatula Bulbus oculi	0.00±0.00	0.00±0.00	0.92±0.59	p>0.05	p<0.001	p<0.001	n.a.	n.a.	00:00:48±00:00:13	-	-	-

Table 7 Sequence probability for the work steps of the right hand (ideal progression course)

ID	Start activity	Stop activity	Surgeon no. 1	Surgeon no. 2	Surgeon no. 3	<i>p</i> values		
						nos. 1 and 2	nos. 1 and 3	nos. 2 and 3
S-1	START	Right hand Paracentesis Paracentesis knife Cornea	0.53±0.51	0.89±0.32	1.00±0.00	<i>p</i> =0.001	<i>p</i> <0.001	<i>p</i> >0.05
S-8	START	Both hands Paracentesis Paracentesis knife Cornea	0.47±0.51	0.11±0.32	0.00±0.00	<i>p</i> =0.001	<i>p</i> <0.001	<i>p</i> >0.05
S-9	START	Left hand Hold Colibri tweezers Bulbus oculi	0.47±0.51	0.83±0.38	0.24±0.43	<i>p</i> =0.02	<i>p</i> >0.05	<i>p</i> <0.001
S-10	START	Left hand Hold Micro spatula Bulbus oculi	0.00±0.00	0.00±0.00	0.67±0.48	<i>p</i> >0.05	<i>p</i> <0.001	<i>p</i> <0.001
1-2	Right hand Paracentesis Paracentesis knife Cornea	Right hand Inject Healon® Chamber ant	0.42±0.5	0.56±0.51	0.92±0.27	<i>p</i> >0.05	<i>p</i> <0.001	<i>p</i> =0.004
1-6	Right hand Paracentesis Paracentesis knife Cornea	Right hand Inject Vision blue® Chamber ant	0.03±0.17	0.28±0.46	0.00±0.00	<i>p</i> <0.001	<i>p</i> >0.05	<i>p</i> <0.001
2-3	Right hand Inject Healon® Chamber ant	Right hand Capsulorhexis Rhexis cannula Capsulalentic	0.84±0.34	0.82±0.38	0.81±0.37	<i>p</i> >0.05	<i>p</i> >0.05	<i>p</i> >0.05
3-2	Right hand Capsulorhexis Rhexis cannula Capsulalentic	Right hand Inject Healon® Chamber ant	0.01±0.04	0.10±0.24	0.00±0.00	<i>p</i> =0.004	<i>p</i> >0.05	<i>p</i> =0.001
3-4	Right hand Capsulorhexis Rhexis cannula Capsulalentic	Right hand Cut Lancet clear cut Cornea	0.94±0.22	0.68±0.4	0.90±0.28	<i>p</i> =0.006	<i>p</i> >0.05	<i>p</i> =0.02
4-5	Right hand Cut Lancet clear cut Cornea	Right hand Excision material Utrata's tweezers Capsulalentic	0.99±0.08	1.00±0.00	0.94±0.22	<i>p</i> >0.05	<i>p</i> >0.05	<i>p</i> >0.05
5-5	Right hand Excision material Utrata's tweezers Capsulalentic	Right hand Excision material Utrata's tweezers Capsulalentic	0.07±0.18	0.03±0.12	0.10±0.20	<i>p</i> >0.05	<i>p</i> >0.05	<i>p</i> >0.05
5-E	Right hand Excision material Utrata's tweezers Capsulalentic	END	0.93±0.18	0.97±0.12	0.86±0.27	<i>p</i> >0.05	<i>p</i> >0.05	<i>p</i> >0.05
6-7	Right hand Inject	Right hand Irrigate	0.17±0.38	0.25±0.43	0.00±0.00	<i>p</i> >0.05	<i>p</i> =0.02	<i>p</i> =0.005

Table 7 (continued)

ID	Start activity	Stop activity	Surgeon no. 1	Surgeon no. 2	Surgeon no. 3	<i>p</i> values		
						nos. 1 and 2	nos. 1 and 3	nos. 2 and 3
7-2	Vision blue®	Sauter cannula						
	Chamber ant	Chamber ant						
	Right hand	Right hand	0.15±0.35	0.33±0.49	0.00±0.00	<i>p</i> >0.05	<i>p</i> >0.05	<i>p</i> <0.001
8-2	Irrigate	Inject						
	Sauter cannula	Healon®						
	Chamber ant	Chamber ant						
8-9	Both hands	Right hand	0.36±0.49	0.06±0.24	0.00±0.00	<i>p</i> =0.002	<i>p</i> <0.001	<i>p</i> >0.05
	Paracentesis	Inject						
	Paracentesis knife	Healon®						
9-E	Cornea	Chamber ant						
	Both hands	Left hand	0.42±0.50	0.11±0.32	0.00±0.00	<i>p</i> =0.004	<i>p</i> <0.001	<i>p</i> >0.05
	Paracentesis	Hold						
9-9	Paracentesis knife	Colibri tweezers						
	Cornea	Bulbus oculi						
	Left hand	END	0.83±0.27	0.71±0.31	0.23±0.42	<i>p</i> >0.05	<i>p</i> <0.001	<i>p</i> <0.001
10-E	Hold							
	Colibri tweezers							
	Bulbus oculi							
10-E	Left hand	Left hand	0.14±0.25	0.25±0.30	0.01±0.07	<i>p</i> >0.05	<i>p</i> =0.009	<i>p</i> <0.001
	Hold	Hold						
	Colibri tweezers	Colibri tweezers						
10-E	Bulbus oculi	Bulbus oculi						
	Left hand	END	0.00±0.00	0.00±0.00	0.70±0.43	<i>p</i> >0.05	<i>p</i> <0.001	<i>p</i> <0.001
	Hold							
10-E	Micro spatula							
	Bulbus oculi							

The treatment profile of surgeon no. 3 appeared to be distinctly different from those of the other two surgeons. With him, work step repetitions occurred less frequently, for instance concerning the work step ‘Inject Healon® with right hand in chamber anterior’. His work steps had a shorter duration, for instance ‘Capsulorhexis with rhexis cannula’. Furthermore, he had a distinct preference concerning the instrument used to ‘Hold bulbus oculi’ as compared to surgeon nos. 1 and 2.

It was furthermore possible to identify the differences in the activity sequences in the treatment profiles, as shown at the example of the sequence ‘Paracentesis with right hand’ and ‘Injection of Healon®’. Surgeon no. 3 had a probability of occurrence of 92% concerning these activity sequences on his primary route, while the profile of surgeon no. 1 showed 56% and the profile of surgeon no. 2 showed 42% probability. Here, the great differences between the three surgeons can be explained by the performance of additional surgical work steps, namely ‘Inject Vision Blue®’ and ‘Irrigate with sauter cannula’ as performed by surgeon nos. 1 and 2. We cannot make a

detailed analysis whether this surgical decision was necessary for the individual patient.

From the presented results, a concrete recommendation for the advanced surgical training can be derived. Firstly, a profound exchange of experience would be very useful. Surgeon no. 3, for instance, had the least repetitions and usually shortest performance times. Also, a training of the work step ‘Paracentesis with right hand’ could lead to an amelioration of results.

The presented data acquisition method allows for a detailed description of surgical processes and has been validated profoundly in previous studies [26]. At the same time, the validity of the presented results was secured by the extensive training and instruction of the observers. In previous studies, it has already been evaluated that it is possible to compute a gSPM from a number of iSPMs. This strategy allowed for representative computing of a treatment profile by preserving the variability of the surgical processes on the one hand and by eliminating infrequently occurring surgical activities on the other hand. It was also shown that gSPM generated

from iSPMs lead to the procedure course that was recommended by clinical guidelines [16].

An improvement of the presented study might be the control of the allocation of patients to the single surgeons. In this study, this allocation was not performed on the basis of age, gender, or severity of affliction, but it was regarded as randomized, because it can be assumed that the surgeon cannot chose his patients in his normal work either. Nevertheless, an influence of different surgical severity cannot be excluded. The examination of these influences remains to be done in future clinical studies. Furthermore, the setting of one surgeon performing inpatient procedures and two surgeons performing outpatient procedures was chosen on purpose to demonstrate the feasibility of the approach to compare treatment profiles between surgeons performing the same strategy (surgeon nos. 1 vs. 2) and surgeons performing different strategies (surgeon nos. 1 resp. 2 vs. 3). Finally, we have intentionally refrained from discussing the reasons for the determined temporal differences in detail, because after the demonstration of the feasibility of the generation of surgeon–individual treatment profiles, the design of clinical studies can be featured.

Conclusion

The success of an ophthalmological department mainly depends on the capabilities of the surgical staff. We showed that it is possible to identify SiTP to promote advanced training of surgical staff and therefore to support optimal patient treatment service. By means of the feasibility study, it was shown that detailed profiles could be gathered with the help of Surgical Process Modeling that provides an exact, validated and objective decision base for the support of surgical teaching in the realm of evidence-based eye surgery.

Further extensions of treatment profiles are conceivable based on the presented results of this study. The computation of treatment profiles for using different surgical strategies or different surgical instruments is possible due to the availability of the method. These assessments could be done in cooperation with ophthalmologic societies to identify the best-practice know-how for the optimal patient care.

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