Feasibility of Network-Based, Online Endovascular Simulator Training in Real Time: Results from a Pilot Study

Machbarkeit eines online durchgeführten endovaskulären Simulatortrainings in Echtzeit: Ergebnisse einer Pilotstudie

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ABSTRACT

Purpose To test the feasibility of an online, simulator-based comprehensive interventional radiology (IR) training curriculum in times of COVID-19-induced travel restrictions.

Materials and Methods A network of six VIST simulators (Mentice, Gothenburg, Sweden) was installed in six geographically different radiology departments. Two courses with six sessions each took place. 43 participants were recruited on a voluntary basis among local residents. The training sessions were conducted in real time with interconnected simulation devices and were led by experts in the field of IR on a rotational basis. The participants attitude toward various topics was quantified before and after training on a seven-point Likert scale (1 = "not at all", 7 = "to the highest degree"). In addition, post-course surveys were conducted.

Results The courses led to an improvement for all items compared with baseline: interest in IR (pre: 5.5, post: 6.1), knowledge of endovascular procedures (pre: 4.1, post: 4.6), likelihood of choosing IR as a subspecialty (pre: 5.7, post: 5.9). Experience with endovascular procedures (pre: 3.7, post: 4.6) improved significantly ($p = 0.016$). In the post-course surveys high satisfaction rates with the pedagogical approach (mean 6), the teaching content (mean 6.4), and the duration and frequency of the course (mean 6.1) were observed.

Conclusion The implementation of a simultaneous endovascular online training curriculum in different geographic locations is feasible. The curriculum has the potential to meet the demand for training in IR in times of COVID-19-associated travel restrictions and can complement future training in the context of radiologic congresses.

Key Points:

- The implementation of a simultaneous endovascular online training curriculum in different geographic locations is feasible. For interested residents, the presented online curriculum can offer a low-threshold and comprehensive entry into the world of interventional radiology at the site of their training.

ZUSAMMENFASSUNG

Ziel Evaluation eines umfassenden, simulatorgestützten Online-Curriculums für interventionelle Radiologie (IR) in Zeiten von COVID-19-bedingten Reisebeschränkungen.

Material und Methoden Ein Netzwerk von 6 VIST-Simulatoren (Mentice, Göteborg, Schweden) wurde in 6 geografisch unterschiedlichen radiologischen Abteilungen installiert. Es fanden 2 Kurse mit jeweils 6 Sitzungen statt. 43 Teilnehmer wurden auf freiwilliger Basis aus den lokalen Weiterbildungsassistenten rekrutiert. Die Schulungen wurden in Echtzeit mit den vernetzten Simulationsgeräten durchgeführt und ab-

wechselnd von Experten auf dem Gebiet der IR geleitet. Die Einstellung der Teilnehmer zu verschiedenen Themen wurde vor und nach der Schulung auf einer siebenstufigen Likert-Skala (1 = „überhaupt nicht“, 7 = „in höchstem Maße“) erfasst. Darüber hinaus wurden Umfragen nach dem Kurs durchgeführt.

Ergebnisse Die Kurse führten bei allen Items zu einer Verbesserung im Vergleich zum Ausgangswert: Interesse an der IR (pre 5,5, post 6,1), Wissen über endovaskuläre Verfahren (pre 4,1, post 4,6), Wahrscheinlichkeit, IR als Subspezialität zu wählen (pre 5,7, post 5,9). Die Erfahrung mit endovaskulären Verfahren (pre 3,7, post 4,6) verbesserte sich signifikant ($p = 0,016$). In den Umfragen nach dem Kurs wurden hohe Zufriedenheitsraten mit dem didaktischen Ansatz (Mittelwert 6), den Lehrinhalten (Mittelwert 6,4) und der Dauer und Häufigkeit des Kurses (Mittelwert 6,1) festgestellt.

Schlussfolgerung Die Durchführung eines gleichzeitigen endovaskulären Online-Curriculums an verschiedenen geografischen Standorten ist machbar. Das Curriculum hat das Potenzial, die Nachfrage nach IR-Schulungen in Zeiten von COVID-19-bedingten Reisebeschränkungen zu befriedigen und kann künftige Schulungen im Rahmen von radiologischen Kongressen ergänzen. Für interessierte Weiterbildungsassistenten kann mit dem vorgestellten Online-Curriculum am Ort ihrer Ausbildung ein niedrigschwelliger und umfassender Einstieg in die Welt der interventionellen Radiologie angeboten werden.

Kernaussagen:

- Die Durchführung eines simultanen, endovaskulären Online-Schulungsprogramms an verschiedenen geografischen Standorten ist machbar. Für interessierte Weiterbildungsassistenten kann mit dem vorgestellten Online-Curriculum am Ort ihrer Ausbildung ein niedrigschwelliger und umfassender Einstieg in die Welt der interventionellen Radiologie angeboten werden.

Zitierweise

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Introduction

The travel restrictions during the COVID-19 pandemic pose a serious problem in the continuous training and recruiting of personnel. A consequence of the ongoing COVID-19 pandemic is the need for social distancing and the adoption of remote communication paths whenever possible. A recent survey among neurointerventionalists found high interest on the part of the participants in general online forums, case discussion forums, and access to video streaming for live mentoring and support [1].

The benefit of simulation training in endovascular medicine has been proven in a number of recent studies [2, 3]. Physicians with various levels of expertise benefit from simulation training in endovascular medicine. Endovascular simulator training improved students' attitude towards interventional radiology, increased the likelihood of them choosing interventional radiology as a subspecialization, and might ease recruitment problems [4]. Simulation training of residents resulted in a shorter total intervention time, less fluoroscopy time, and less contrast agent usage in neurointerventional procedures [3]. To attract more radiologists for interventional radiology, it must be recognized early as a career option [5]. Due to advances in streaming technology, remote proctoring by endovascular specialists of geographically distant interventionalists is feasible and patient safety can be increased [6]. Modern simulators allow the transmission of real patient data. Complex elective examinations can be practiced, and different therapeutic options can be evaluated in advance with these individualized datasets.

The "Deutsche Gesellschaft für Interventionelle Radiologie und minimalinvasive Therapie" (DEGIR) is the largest national society of interventional radiologists in Europe. The organization has been offering simulation-based training sessions as part of radiological congresses for a number of years to address the outlined issues. Due to the COVID-19 pandemic, these congresses were cancelled with some being replaced by virtual and online meetings.

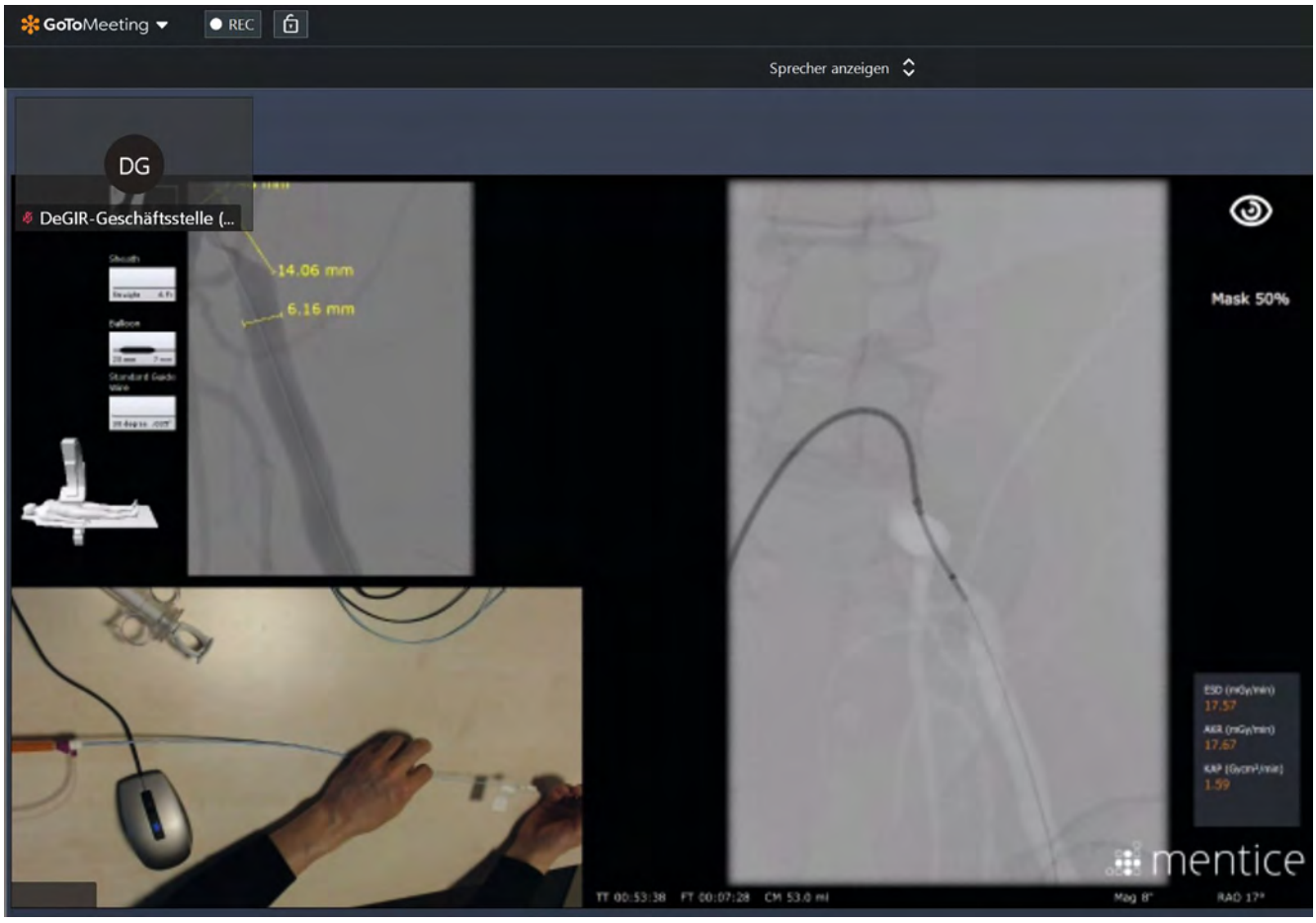
To meet the ongoing demand for simulation training in interventional radiology and to expand the range of endovascular simulation training in the future, the presented pilot project was developed.

The aim of our study was to test if a curriculum of network-based geographically different endovascular training sessions led by experts in the field is feasible and to report initial results from this curriculum.

Materials and Methods

In a pilot phase, participating departments volunteered for the training sessions. The necessary hardware and a construction manual for the setup of the simulation device were sent to the participating centers in advance. These six sites were connected to the internet during the courses. Real-time recordings of the fluoroscopic images, the user interface of the simulator program, a camera that filmed the hands and materials of the course participants, and a camera for video telephony could be exchanged among each other. For this purpose, an online conference program was used (www.goto.com). The most suitable of these options could be selected for the respective course situation. ▶ **Fig. 1** shows an example of a screenshot of a training session.

The expert performed the intervention using a step-by-step approach. It was possible for the participants to observe the materials and simulator settings selected by the instructor and to observe the hand movements and fluoroscopic recordings per-



▶ **Fig. 1** Screenshot of a training session. Shown is the demonstration of a percutaneous transluminal angioplasty of a pelvic stenosis. The instructor's hands are shown on the bottom left, the selected materials and the virtual patient and C-arm position are shown on the top left. The generated measurement image for stenosis grading is at the top center, and the right edge of the screen shows the fluoroscopy image where the roadmap technique is currently being used to treat the iliac artery stenosis. These images are transmitted in real time. If necessary, the participants can communicate with each other and with the instructor via video telephony.

▶ **Abb. 1** Screenshot einer Trainingssession. Dargestellt ist die Demonstration einer perkutanen transluminalen Angioplastie einer Beckenstenose. Unten links sind die Hände des Instruktors zu sehen, oben links die ausgewählten Materialien und die virtuelle Patienten- und C-Bogen-Position. Das erzeugte Messbild zur Stenosegraduierung befindet sich oben in der Mitte und der rechte Bildschirmrand zeigt das Fluoroskopiebild, wo gerade in Roadmaptechnik die Behandlung der Beckenarterienstenose durchgeführt wird. Diese Bilder werden in Echtzeit übertragen. Die Teilnehmer können bei Bedarf währenddessen über Videotelefonie miteinander und mit dem Instruktor kommunizieren.

formed by the instructor in real time. The residents watched the intervention and reproduced the demonstrated steps.

In turn, the instructor was able to observe the participants' manipulations and fluoroscopic images. Therefore, the instructor demonstrated part of the intervention, then provided assistance with any problems the course participants might have had, and then continued with another part of the intervention until the training goal was achieved. In the meantime, additional video telephony was used to talk to each other.

Hardware

The endovascular training sessions were performed with the vascular intervention system trainer VIST B from Mentice (Mentice AB, Gothenburg, Sweden), integrated in the VIST LAB. The VIST LAB consists of a laptop with a touchscreen function for selecting scenarios and materials. On this laptop the live stream of the expert and the other participants can be watched plus one additional monitor where the live image of the intervention is depicted. A camera is used to depict the manipulation of the material. The simulator consists of a box with an insertion sheath, which serves as the access point for all materials. The introduced wires and catheters are detected by sensors, which generate realistic resistance to the manipulations. The manipulations of the trainee are transferred into a virtual patient anatomy and displayed on the screens in real time. A footswitch with two pedals and a control panel for rotating the virtual C-arm as well as the virtual patient table and other settings are connected to the device. In addition, a syringe to simulate the injection of contrast medium and a slide switch to simulate the placement of stents are connected to the simulator. For each simulation, authentic angiographic materials such as microcatheters and sheaths as well as diagnostic catheters

were used. After the completion of each training, the amount of contrast agent, the total time, and the fluoroscopy time are depicted and saved. In total, six devices were used in six participating radiology departments.

Curriculum

Participants were recruited among residents from the participating departments on a voluntary basis. The simultaneous training of one to three residents with one simulation device is feasible based on experience from previous simulation courses. In addition to the course participants, an experienced interventional radiologist was available at each simulator site. The curriculum consisted of two courses with six lessons that lasted for one hour with various cases from all fields of endovascular radiology.

In creating the curriculum, care was taken to provide an overview of all endovascular interventional radiology procedures from head to toe.

At the beginning of each course, the instructor gave a brief introduction to the respective case and an overview of the disease being treated. However, the main focus of the course was the manual execution of the intervention.

Then the expert performed the intervention with a step-by-step approach as described above.

The individual courses build on each other. The courses started with simpler interventions and more complex procedures were introduced later on. For both series of courses, an instruction session was given, and the function of the device was explained by means of a stent implantation in the common iliac artery on the first day of the course. In the following session, the knowledge of recanalizing measures was expanded by means of stent implantations in the superficial femoral artery. The following exact course content varied somewhat in both courses, as can be seen in ▶ **Table 1**. Vascular occlusion measures were practiced with separate courses in which a uterine artery and a gastrointestinal hemorrhage were embolized and transarterial chemoembolization of the liver was performed.

Neurovascular cases with the embolization of an aneurysm and thrombectomy of the middle cerebral artery were presented and practiced.

▶ **Table 1** depicts an overview of the participating sites and the accomplished curriculum in the first two courses.

▶ **Table 1** Overview of the completed curriculum of the first and second course and the involved teaching sites.

▶ **Tab. 1** Übersicht über den absolvierten Lehrplan des ersten und zweiten Kurses und die beteiligten Unterrichtsorte.

Course number	Teaching site	Topic
1	Helios Clinic Krefeld	introduction to the device/recanalization of an ipsilateral iliac artery stenosis
1	Saarland University Medical Center	recanalization of the superior femoral artery
1	Horst Schmidt Clinic Wiesbaden	recanalization below the knee
1	Clemens Hospital Muenster	intracranial aneurysm coiling
1	Technical University of Munich	transarterial chemoembolization
1	Hannover Medical School	renal artery stenosis
2	Helios Clinic Krefeld	introduction to the device/recanalization of an ipsilateral iliac artery stenosis
2	Technical University of Munich	pelvic and femoral arterial recanalization
2	Saarland University Medical Center	emergency interventions
2	Hannover Medical School	oncologic interventions
2	Technical University of Munich	urogenital interventions
2	Clemens Hospital Muenster	acute ischemic stroke

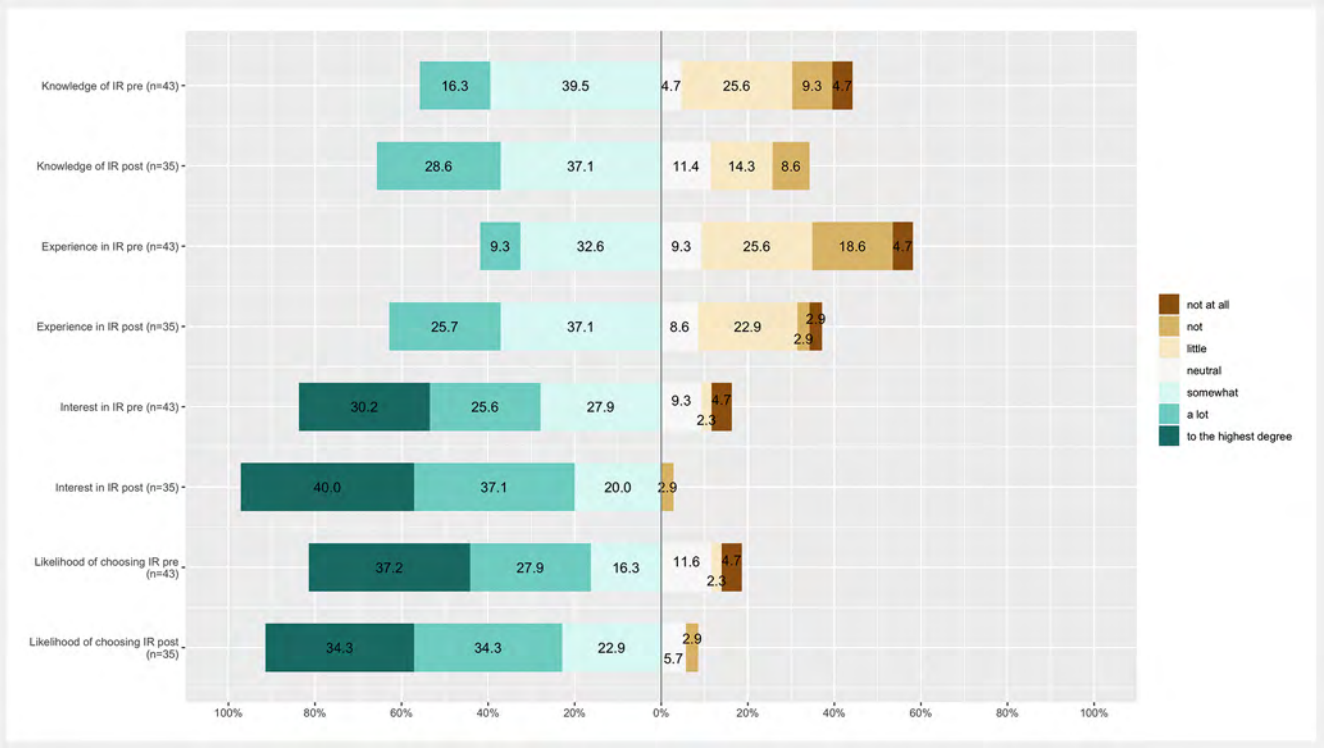
Survey design

The participating residents completed questionnaires before and after the course. Before the survey, the participants were informed that the survey was anonymous and for research purposes only. All participants gave written informed consent to participate in the presented study.

The questionnaire consisted of four identical questions before and after the course. No objectively measurable learning progress was queried during the evaluation of the course. Participants rated their interest in interventional radiology, the likelihood of them choosing interventional radiology as a subspecialty, their experience with endovascular procedures, and their knowledge of endovascular procedures. Six additional questions after the course recorded the overall satisfaction with the course, the recommendation rate of the course, the satisfaction with the duration and frequency of the course, the satisfaction with the teaching content and the pedagogical approach, and the agreement with the statement that the course should be part of the training regulations of residency training. A seven-point Likert scale was used in the survey (1 = “not at all”, 2 = “not”, 3 = “little”, 4 = “neutral”, 5 = “somewhat”, 6 = “a lot”, 7 = “to the highest degree”).

Data collection

Initially, the responses of 14 participants were recorded using excel spreadsheets. The rest of the survey was conducted with an online survey tool (Survey monkey, www.surveymonkey.com). The results were analyzed with R 3.6.0 and the figures were created with R as well (A language and Environment for Statistical Computing, R Foundation for Statistical Computing, https://www.R-project.org, assessed August 2020) [7]. Statistical significance was tested with the Wilcoxon test for dependent samples. A p-value less than 0.5 was considered statistically significant.



▶ **Fig. 2** Depiction of pre- and post-course survey results in a centered stacked bar plot. The Likert scale defined 7 categories. The percentage of the respective answers is indicated.

▶ **Abb. 2** Darstellung der Umfrageergebnisse vor und nach dem Kurs in einem zentrierten, gestapelten Balkendiagramm. Die Likert-Skala umfasste 7 Kategorien. Angegeben ist der prozentuale Anteil der jeweiligen Antworten.

Results

A total of 43 participants took part in both courses. All participants took the survey at the beginning of the course. The questionnaire after the courses was completed by 35 residents (81 %). 43 residents completed the questionnaire before the course. 28 (65 %) of the participants were male and 15 (35 %) were female. The mean age of the participants was 31 years and the median age was 30 years (IQR 28–32.5).

Compared to the pre-course survey, we found higher approval rates for all post-course questions.

Respondents' interest in IR improved from an average of 5.5 ("neutral" to "somewhat") to 6.1 ("a lot"). After the course, the percentage of respondents choosing "to the highest degree" rose from 30.2 % to 40 % and the percentage of negative to neutral results decreased from 15.3 % to 2.9 %.

Compared to the pre-course survey, the residents' knowledge about interventional procedures improved from an average of 4.1 ("neutral") to 4.6 in the range of "somewhat" to "a lot".

We found significant improvement ($p = 0.016$) in the residents' self-reported experience with interventional procedures from an average of 3.7 ("little" to "neutral") to 4.6 ("neutral" to "somewhat").

The likelihood of choosing IR as a subspecialty in the future rose from an average of 5.7 to 5.9 ("somewhat" to "a lot"). The percentage of negative to neutral results decreased from 18.6 % to 8.6 %.

High approval rates were observed in the additional post-course questions. The average overall satisfaction with the course was 6.2 ("a lot") and the median was 6 (IQR 6–7). No negative or neutral results were measured. The pedagogical approach received an average approval rate of 6 ("a lot"), the median was 6 (IQR 6–7), and the satisfaction with the teaching content was 6.4 ("a lot"), the median was 6 (IQR 6–7). The average satisfaction with the duration and frequency of the course was 6.1 ("a lot"), the median was 6 (IQR 6–7) and the average approval rate of the statement that the course should be part of the training regulations in residency training was 5.9 ("a lot"), the median was 6 (IQR 5–7).

The average level of recommendation to fellow residents was given by the participants as 6.3, the median was 6 (IQR 6–7). ▶ **Table 2** provides an overview of the pre-course and post-course survey and the associated statistical tests. ▶ **Fig. 2, 3** present the results of the pre-course and post-course surveys.

Discussion

In the present study we demonstrate that an online, endovascular training curriculum with simulators in different geographical locations is feasible in real time. The network incorporated six mobile simulator sites that served as training sites as well as supervising

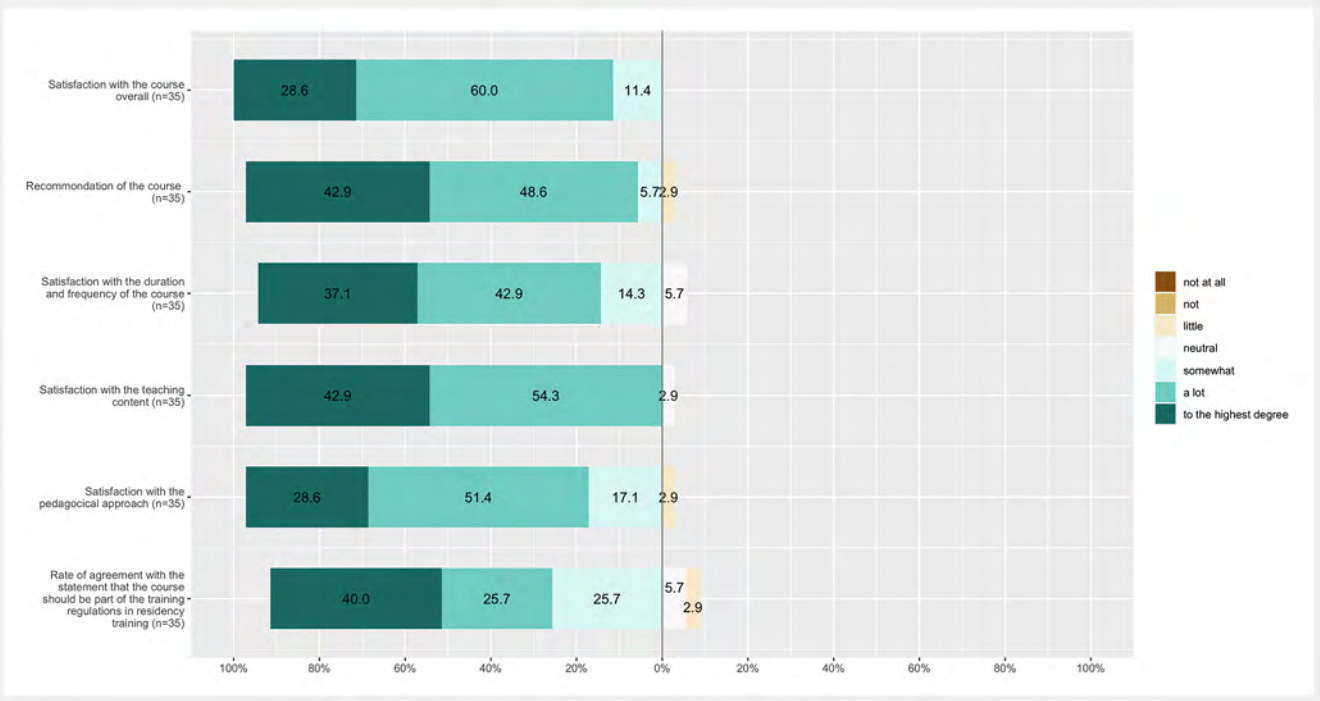


Fig. 3 Depiction of the additional post-course survey results in a centered stacked bar plot. The Likert scale defined 7 categories. The percentage of the respective answers is indicated.

Abb. 3 Darstellung der Ergebnisse der zusätzlichen Umfrage nach dem Kurs in einem zentrierten, gestapelten Balkendiagramm. Die Likert-Skala definierte 7 Kategorien. Angegeben ist der prozentuale Anteil der jeweiligen Antworten.

▶ **Table 2** Survey comparing pre-course and post-course results. Statistical significance was tested with the Wilcoxon test for dependent samples. The asterisk indicates a significance level of a p-value of less than 0.05.

▶ **Tab. 2** Umfrage zum Vergleich der Ergebnisse vor und nach dem Kurs. Die statistische Signifikanz wurde mit dem Wilcoxon-Test für abhängige Stichproben getestet. Das Sternchen kennzeichnet ein Signifikanzniveau mit einem p-Wert von weniger als 0,05.

Item	Pre-seminar	Post-seminar	P-value
Interest in IR, median (IQR); mean	6 (5–7); 5.5	6 (6–7); 6.1	0.07 503
Likelihood of becoming an interventional radiologist, median (IQR); mean	6 (5–7); 5.7	6 (5–7); 5.9	0.936
Experience with endovascular procedures, median (IQR); mean	4 (3–5); 3.7	5 (3–6); 4.5	0.01 606*
Knowledge about endovascular procedures, median (IQR); mean	5 (3–5); 4.1	5 (4–6); 4.6	0.1404

lecture sites on a rotational basis. We observed a high level of satisfaction among the participants and a significant gain regarding self-reported experience in interventional radiology. Our course format appealed to participants with a high level of preexisting interest in interventional radiology that could even be increased through the course.

Our results are in good agreement with the results of two previous studies that evaluated the effect of practical training on students with a dedicated course where a significant improvement of endovascular skills was noted [8, 9]. A superior effect of simulator training compared to theoretical seminars was found in an earlier study with medical students [4].

This significant gain of experience in specific manual intervention techniques of highly motivated residents might constitute a unique selling point of simulator training.

In times of upcoming intensified recruitment problems, residents need to be trained more efficiently for a career in interventional radiology to prevent personnel shortages and a concomitant loss of standing for interventional radiology. Simulator-based training represents a low-threshold introduction to the world of endovascular radiology. These training sessions can be used to train residents with an even lower threshold at the location of their residency.

An often-encountered and weighty argument against using endovascular simulators in residency training on a routine basis is

the high acquisition costs. The purchase of a simulation device does not pay off for many, especially small and medium-sized, departments. The presented model with routinely rotating simulation devices which belong to a professional society could solve this problem. Interested departments can train their assistants extensively in this way with a device for a few months before the device is sent on to another hospital. In this way, higher utilization rates can be achieved than with a stationary device and expert knowledge can be disseminated more easily without geographic restrictions.

Even after the end of the current travel restrictions, the presented concept represents a useful supplement to training in the context of radiological congresses to meet the growing need for standardized and structured training throughout Europe.

Furthermore, the presented network represents a prerequisite for training cases with real patient data. It seems feasible that a supervised training session run together with a geographically distant expert in the field can be performed prior to an intervention.

Certification programs of professional endovascular societies (e. g. DEGIR, CIRSE) face the problem that an essential proportion of endovascular therapy consists of manual skills. These manual skills cannot be quantified with the established written and oral exams. The presented study might serve as a blueprint to establish simulation-based examinations in different geographical locations to quantify these essential therapeutic skills.

Limitations

Limitations of our study include the relatively small number of participants. As the presented training curriculum commences, we are confident that larger numbers of participants will be able to be surveyed in future studies. A further limitation of the study is the considerable technical effort required. Fast and stable data connections, coordination efforts, and the availability of functioning simulation devices at the respective locations are a prerequisite for a functioning training program. Finally, the presented program is only made possible by the presence and commitment of a sufficient number of qualified experts in the field.

Conclusion

The realization of a network-based endovascular online training curriculum in different geographical locations is feasible. The comprehensive curriculum has the potential to meet the demand for IR training in times of travel restrictions and can complement future training in the context of radiologic congresses. For interested residents, the presented online curriculum can offer a low-threshold and comprehensive entry into the world of interventional radiology at the site of their training.

CLINICAL RELEVANCE OF THE STUDY

- Simulator-based training in endovascular methods led by experts in the field at different geographical locations is feasible.
- A network of simulators allows implementation of a comprehensive endovascular training program in times of COVID-19-associated travel restrictions.
- The curriculum has the potential to complement future training in the context of radiologic congresses.
- For interested residents, the presented online curriculum can offer a low-threshold and comprehensive entry into the world of interventional radiology at the site of their training.

Conflict of Interest

The authors declare that they have no conflict of interest.

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