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ORIGINAL RESEARCH

Remote Robotic Neurointervention: Overcoming Procedural and Connectivity Challenges

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ABSTRACT

BACKGROUND AND PURPOSE: Access to endovascular interventions for neurointerventional procedures remains concentrated in metropolitan centers, limiting availability in smaller cities, rural regions, and developing nations. The feasibility of remote robotic intervention faces several challenges, including enabling full robotic navigation, managing contrast injection, and maintaining stable network connectivity. This study addresses these key obstacles.

METHODS: A robotic system was deployed at the Translational Research Imaging Center (TRIC) lab at UCLA. Connectivity was assessed both before and during the procedures. Five remote Neurointerventionalists operated four devices—two novel steerable catheters, one off-the-shelf microcatheter, and one guidewire—from femoral access to the middle cerebral artery (MCA) in a silicone vascular model. Radiopaque contrast injections were performed, and audiovisual communication was maintained throughout. Connectivity metrics, including round-trip time (RTT) and bandwidth, were monitored. Primary endpoints included successful navigation to the MCA within 15 minutes, first-attempt vessel entry rate, and episodes of tool-tip contact with the vessel wall.

RESULTS: Following catheter placement in the femoral sheath, all procedures were fully robotically controlled without bedside intervention. Procedural times ranged from 11:01 to 14:00 minutes, with a mean RTT below 150ms. Two brief episodes of unsafe latency (RTT >150 ms) were recorded. First-attempt vessel entry was successful in 84.2% of cases, and minimal vessel wall contact occurred (1-2 episodes per procedure).

CONCLUSIONS: This study demonstrates the feasibility of remote robotic neurointervention, effectively addressing key challenges in robot-assisted endovascular procedures and network connectivity management.

ABBREVIATIONS: PTZ = Pan Tilt Zoom Camera; RTT = round-trip time; TRIC = Translational Research Imaging Center lab at UCLA ; RR = Remedy Robotics; LCCA = Left Common Carotid Artery; RCFA = right common femoral artery; ACA = Anterior Cerebral Artery; ICA = Internal Carotid Artery.

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SUMMARY SECTION

PREVIOUS LITERATURE: Endovascular intervention has been developed and remains concentrated in major metropolitan hospitals, resulting in an uneven distribution of care for patients in underserved and rural areas. Remote robotic intervention has been proposed as a solution to this issue, but the implementation of fully remote robotic intervention faces several challenges, including the development of robotic systems that enable full robotic navigation across entire procedures, the management of contrast injection, and the maintenance of stable network connectivity.

KEY FINDINGS: This research suggests that many of the challenges facing remote robotic neurointervention are solvable. A robotic system was integrated into a hospital imaging lab allowing multiple physicians to conduct an entire simulated procedure remotely. Connectivity, latency, contrast management and communication challenges were addressed across significant distances.

KNOWLEDGE ADVANCEMENT: This research demonstrates a step forward in the development of remote robotic neurointervention. While a number of practical challenges remain, this study addresses critical barriers and suggests that it is technically feasible for neurointerventionalists to remotely control a robotic system capable of completing entire procedures remotely.

INTRODUCTION

Access to endovascular intervention for neurointerventional procedures remains predominantly concentrated in major metropolitan hospitals (Yan et al. 2022), creating significant geographic disparities in care. This uneven distribution limits treatment options for patients

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in rural and underserved areas, where timely intervention is often critical, particularly for conditions such as large vessel occlusion stroke. Time-to-treatment is a key determinant of patient outcomes, with delays significantly increasing the risk of morbidity and mortality outcomes (Mulder et al. 2018).

This study explores the potential of a robotic system to address these access barriers by enabling remote, fully robotic navigation of endovascular tools without the need for manual bedside assistance once vascular access is established. For remote robotic intervention to be feasible, several critical capabilities must be integrated. These include the ability to navigate endovascular devices from the access site to the target pathology, maintain and monitor preoperative and intraoperative network connectivity, ensure seamless communication between remote operators and onsite teams, and manage guidewires, microcatheters, and fluidics with precision and safety. This study aims to evaluate the feasibility of the robotic system in performing these essential tasks. Future studies will assess the robot's ability to control end effector tools at the pathology site and manage procedural complications, further advancing the field of robotic neurointervention.

METHODS

The study was a collaboration between the University of California Stroke Consortium's Robotics Committee and Remedy Robotics (RR). RR developed a robotic system designed to optimize access to care and procedural safety in neurointervention. An early prototype of this system was deployed in the Translational Research Imaging Center (TRIC) at the University of California, Los Angeles (UCLA). The primary goal was to allow remote Neurointerventionalists to navigate from femoral access to microcatheter placement in the M2 segment of the middle cerebral artery within 15 minutes, without any bedside assistance; this time threshold was based on the expected time for manual completion of these steps. Secondary goals included evaluating navigation efficiency and assessing potential vascular trauma. Navigation efficiency was assessed by measuring the rate at which operators were able to enter an identified target vessel on the first or subsequent attempt. Potential vascular trauma was assessed by tracking episodes of tool tip contact with the vessel wall. The technical objectives focused on facilitating successful remote control of contrast injection and tool navigation, as well as continuous audiovisual communication between remote operators and on-site personnel. Additionally, the system monitored real-time network connectivity to manage potential latency issues.

Pre and Intraoperative Connection Monitoring

In the days leading up to the procedures, RR monitored connectivity from its San Francisco office to a wired ethernet point at the TRIC lab, serving as a representative remote site. During the procedures, continuous real-time connectivity monitoring was performed, focusing on round-trip time (RTT), bandwidth, and connection stability. RTT, the time taken for a command from a remote operator to be executed and observed, was measured every 10 milliseconds, while bandwidth was measured every second. For each remote user, the study tracked mean RTT, standard deviation (jitter), and episodes of unsafe latency, defined as RTT exceeding 150 milliseconds based on the worst-case minimum time needed for a stiff guidewire to generate enough force to cause vascular injury while traveling at its maximum speed abutting the MCA wall.

System Installation

On the day before the procedure, the robotic system, contrast pump, and necessary endovascular tools were installed in the TRIC lab. The lab equipped with a floor-mounted, single plane Artis Zeego C-arm and table, was chosen to represent the real-world conditions of rural and regional settings where biplane systems may be less common. The robot was connected to a power source, the internet through a wired ethernet connection, and the imaging stream from the C-arm. A pan-tilt-zoom (PTZ) camera was installed with pre-configured views, providing visibility of the femoral access site, bedside assistant, and the robot.

System Setup

On the day of the experiment, a laboratory technologist prepared the silicone vascular model and achieved femoral access using an 8 Fr sheath. The silicone model was connected to a pulsatile pump to allow for realistic contrast injection and flow. The technologist also prepared and primed the dual-head contrast injector, with one chamber loaded with 150 mL of Iohexol (320 mg/mL) and the other with 150 mL of saline. A 7.5 Fr, 105 cm quad-steerable catheter; a 4.5 Fr, 140 cm quad-steerable catheter; a 167 cm Headway Duo microcatheter; and a 200 cm, 0.012" Terumo Headliner guidewire were mounted coaxially to the robot; the robotic system utilized is compatible with straight or pre-curved wires of 0.010-0.035 outer diameter. All tools were mounted onto the robot by the technologist prior to commencement of the case. These instruments were threaded through each other and a feeder located at the front of the robot. All catheters were thoroughly flushed and primed. Sterile tubing was connected from each injector head to a one-way duckbill check valve, with each valve affixed to an afferent arm of a Y-connector. A single line of sterile tubing coming from the efferent arm was split to connect to a side port with a stopcock on a hemostasis valve attached to the luer connectors on both the 7.5 Fr and 4.5 Fr catheters. The lines and catheters were primed with saline, and the stopcock on the 4.5 Fr catheter was kept closed by default.

Catheters

The 7.5Fr and 4.5Fr quad-steerable catheters were designed by Remedy Robotics specifically for use with the robotic system. These catheters are mounted on handles that are intended to be mounted to the robot, making them unsuitable for manual control. Each catheter is engineered with four embedded control wires, evenly spaced around its circumference, allowing for precise articulation in any direction within a 360-degree range. By selectively pulling or releasing the control wires, the robot manipulates the catheter tip to bend toward the corresponding side. Adjusting the tension in adjacent wires enables finer control, allowing the catheter to navigate complex anatomical pathways. The ability to combine movements from different wire pairs provides full 360-degree steerability, making it possible to navigate through tortuous vascular structures. Controlling quad-steerable catheters presents significant challenges. Their complexity requires simultaneous manipulation of multiple control wires, which is difficult to achieve reliably with manual operation. When the catheter rotates

within the anatomy or the C-arm imaging system moves, maintaining consistent and accurate control becomes even more challenging. This is because the orientation of the catheter relative to the image shifts, complicating the steering process. The catheters incorporate proprietary technology that allows them to be steered in any direction—left, right, into, or out of the imaging plane—regardless of the position of the C-arm. This unique capability makes them intuitive to control with a limited learning curve and well-suited for use in complex, real-time endovascular procedures.

Silicone Phantom Model

The silicone phantom used in this study was a combined model of the Mentice AA009 (Tortuous Aorta with Iliac) and COW005 (Circle of Willis), fused to simulate a continuous vascular pathway. This model was then connected to the Mentice TA004 (Aortic Arch Type III) via a clip to represent realistic anatomical conditions. These models provide a standard replica of human vascular anatomy, allowing for accurate simulation of catheter navigation through the aortic arch, iliac, and cerebral vasculature.

Procedure

For this study, clinicians received no prior training and operated the robotic system remotely via their personal computing devices utilizing their respective internet connections and with limited verbal guidance to orientate users to the system. This approach was chosen to assess the system's ease of use without formal instruction. Five remotely located clinicians from four different locations were each sent a unique, password-protected link via email which they accessed on either hospital or public Wifi. By clicking on the link and entering a password, they accessed the robotic control console and monitor at UCLA through a secure, encrypted connection. Once connected, an on-screen interface was displayed on the remote-controlled operator's personal computer including an imaging stream from the C-arm, a live audiovisual stream of TRIC lab and on-screen controls for the robot and fluidics. The operator could click a drop-down menu to view connectivity metrics and alerts were shown if latency thresholds were breached.

Each case began with the manual insertion of the distal 5 cm of the 7.5 Fr, quad steerable catheter into the 8 Fr femoral sheath by the technologist. The robot-to-patient connector was then telescoped over the top of the catheter between the robot and sheath. From this point onwards, remote-controlled operators assumed all control of endovascular tools. All tools were controlled by the operator clicking on buttons displayed on the user interface and navigation was completed by reference to the visual signals from the C-arm feed. Operators were not provided with any tactile feedback (sensation based) or force feedback (resistance, pressure etc), although force sensors were utilized in robot safety systems. Users could communicate with the TRIC lab by an audiovisual link to guide any required movement in the C-arm or table and could use the on-screen interface to control the PTZ camera through pre-defined views.

Throughout the case, users could select the volume, rate, rise time, and start and stop contrast injection via the remote user interface. During the procedure each contrast injection through the 7.5Fr catheter was automatically followed by a 5 mL normal saline flush at a rate of 2.5 mL per second. Users had the option to repeat the flush, adjust the flush settings, or disable it entirely via the user interface. A background Saline flush running at a rate of 1ml/minute ran throughout the entire procedure. As one-way valves were used, no bedside control of fluid management was required during the procedure. Users had the ability to control road mapping directly from the user interface.

Method of Results Collection

An assessor reviewed the procedure videos and recorded the time taken from initiating robotic control in the femoral artery to reaching the middle cerebral artery (MCA), as well as the time spent in each phase of the procedure. Additionally, the assessor used the live image to count the number of times the tool tip contacted the vessel wall in a single plane and the number of failed attempts to enter a target vessel. A target vessel was defined as the next vessel the operator aimed to enter with the endovascular tool. In this phantom model, four target vessels were identified: the aorta, accessed via the femoral artery; the innominate artery or the left common carotid artery (LCCA), both accessed from the aortic arch; the internal carotid artery (ICA), accessed from the common carotid artery; and the middle cerebral artery (MCA), accessed from the ICA.

RESULTS

The users had varying levels of experience, including two final-year neurointerventional fellows from UCSF and three board-certified Neurointerventionalists, one with 35 years of experience. None of the users had significant experience with endovascular robotics.

All users successfully navigated from the right common femoral artery (RCFA) to either the left or right MCA with no bedside assistance. Three users entered the left MCA and two the right MCA. Despite not being specifically instructed, all drivers followed a similar routine. Each navigated the 7.5 Fr quad steerable catheter from the RCFA through the aorta to the arch, through either the Innominate Artery or LCCA, and into the proximal Internal Carotid Artery (ICA). At this point, most users parked the 7.5 Fr catheter, chose to inject radiopaque contrast, and perform road mapping. Following this, users advanced a 4.5 Fr quad steerable catheter through the 7.5 Fr lumen and steered it through the ICA to the distal ICA before injecting contrast again. From there, the 4.5 Fr catheter was steered towards the anterior or middle cerebral arteries. At this point, users parked the 4.5 Fr catheter and used a combination of microcatheter insertion, guidewire insertion, and guidewire roll to navigate into the cerebral vessel of their choice.

Successful first-attempt entry into the target vessel was achieved in 84.2% of cases (16 of 19 attempts). There were three instances of failed target vessel entry, but the target vessel was entered on the second attempt each time. There was minimal visible contact between the steerable tool tip and the phantom wall, with most users encountering only one to two episodes per procedure. This was only assessed on a single imaging plane so there may have been instances of contact with the front or back wall of vessels that were not detected. These results are displayed in Table 1.

Table 1: User demographics and robotic interaction with silicone phantom.

Location	Seniority and experience	Origin	Destination vessel	Failure to enter target vessel on the first attempt	Episodes of bedside contact with robot after tool loading	Episodes of Tool Tip contact with vessel wall
Washington DC	Attending NI (4 yrs)	RCFA	LMCA	0	0	2
UCSF (Driver 1)	Fellow NI* (8 yrs post-grad)	RCFA	LMCA	1; Failed to enter the LCCA at first attempt	0	2
UCSF (Driver 2)	Fellow NI* (2 yrs post-grad)	RCFA	RMCA	1; Entered ACA when attempting to enter RMCA	0	1
Maui	Attending NI (35 yrs)	RCFA	RMCA	0	0	1
UC Davis	Attending NS (15 yrs)	RCFA	LMCA	1; Entered LECA when attempting to enter LICA	0	2

ACA = Anterior Cerebral Artery; RCFA = Right Common Femoral Artery; LMCA= Left Middle Cerebral Artery; RMCA = Right Middle Cerebral Artery; LCCA = Left Common Carotid Artery; LICA = Left Internal Carotid Artery; LECA = Left External Carotid Artery; UCSF = University of California San Francisco; NI = Neurointerventionalist; NS = Neurosurgeon; * At time of test drives

The total procedural times for users who performed the entire navigation ranged between 11:01 and 14:00 minutes. Driver 2 at UCSF took over operating from Driver 1 at UCSF, so Driver 2 commenced navigation at the left MCA and retracted the tools into the Aortic Arch before commencing operation. This resulted in a shorter procedure time. Timing for each stage of the procedure is provided in Table 2. The timings for each stage do not tally up to the entire procedural time as there were multiple instances of remote users pausing to communicate with the onsite team or adjust and view the camera.

Table 2: Time spent on various stages of the procedures.

Location	Time to navigate from SFA to AoA	Time to navigate from AoA to Neck Vessel	Time to navigate through ICA	Time to navigate from distal ICA to destination vessel (measured at M1/M2 junction)	Intra procedure communications and camera adjustments (aggregate)	Total procedural time
Washington DC	1:30	1:45	3:39	0:55	3:12	11:01
UCSF (Driver 1)	1:59	2:01	4:38	0:59	3:59	13:36
UCSF (Driver 2)	-	1:29	5:22	0:53	2:15	9:59
Maui	2:50	1:37	4:06	1:27	4:00	14:00
UC Davis	0:53	1:49	3:58	2:01	2:47	11:28

SFA = Superficial Femoral Artery; AoA = Aortic Arch; ICA = Internal Carotid Artery; UCSF = University of California San Francisco

The round-trip time (RTT) was measured every 10ms during each case. The Mean RTTs were all below the unsafe threshold of 150ms, ranging from 61.7ms to 114.1ms. Jitter, the variation in the time it takes for packets to travel from their source to their destination, was low across all sites ranging from 1.8ms for the remote user in Washington DC and 5.5ms for the remote user in Maui. Total bandwidth required was low, measuring less than 6 Mb/s on all occasions. The remote user controlling the robot from Maui experienced two episodes of unsafe latency, with durations of 200ms and 804ms. During these periods, the software limited the driver's controls to tool retraction and relaxation only. These results are displayed in greater detail in Figures 1 and 2 and Table 3.

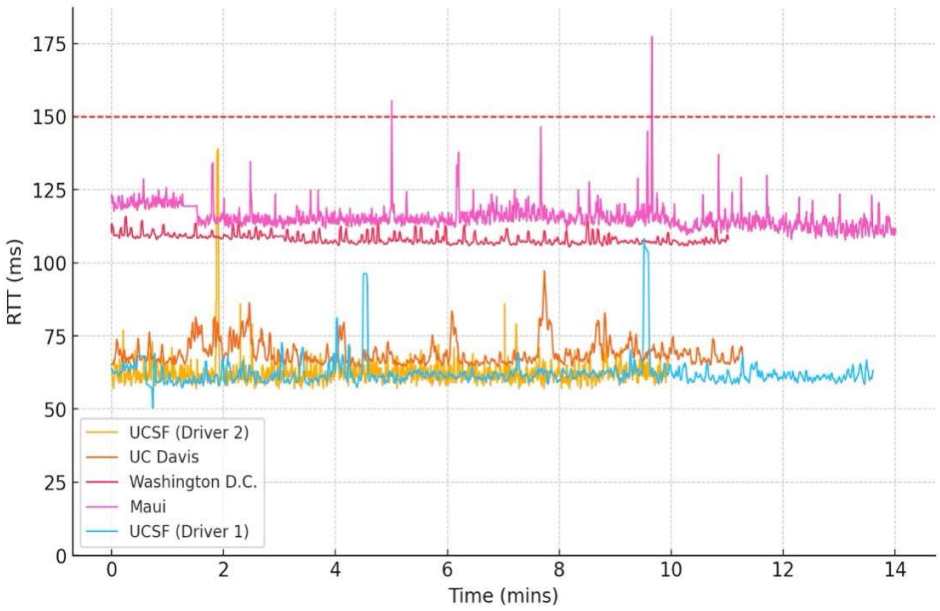

FIG 1. Round Trip Time (RTT) between the robotic system at Hospital A and remote sites

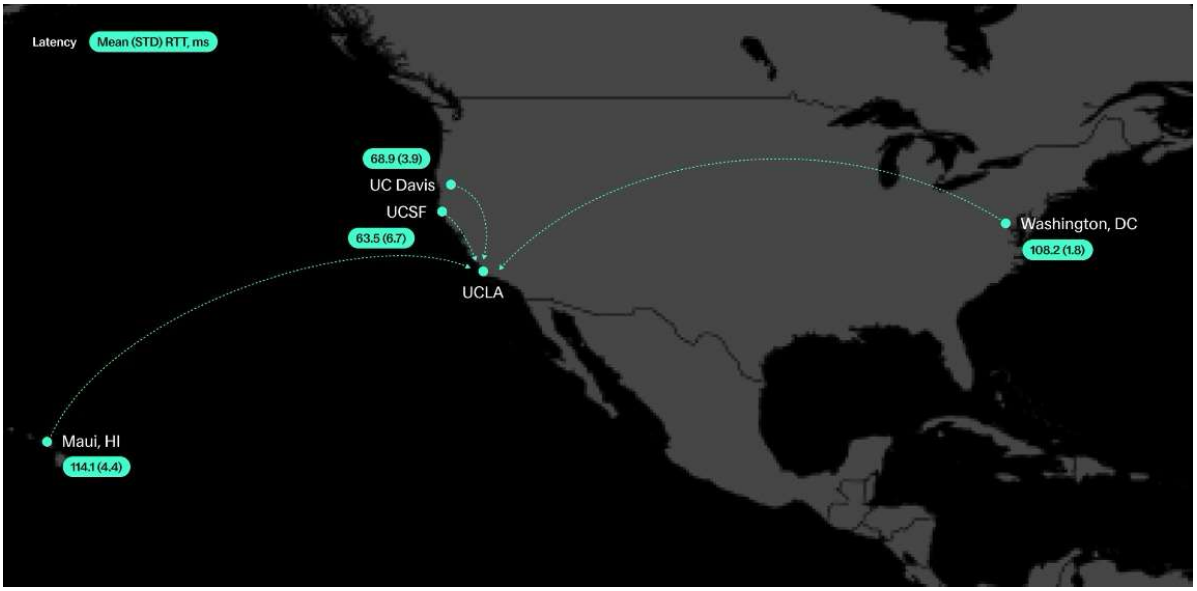

FIG 2. Graphical representation of RTT and jitter from multiple remote sites. STD = Standard Deviation; RTT = Round trip time

Table 3: Connectivity and latency data.

Location	Distance from the TRIC lab (miles)	Connection Type	Mean RTT (ms)	Standard Deviation RTT (ms)	Episodes of unsafe latency	Duration of episodes of unsafe latency (ms)
Washington DC	2679	Wifi (public)	108.2	1.8	0	-
UCSF (Driver 1)	381	Wifi (hospital)	61.7	3.5	0	-
UCSF (Driver 2)	381	Wifi (hospital)	62.5	2.8	0	-
Maui	2487	Wifi (public)	114.1	4.4	2	200, 804
UC Davis	386	Wifi (hospital)	68.9	3.9	0	-

TRIC = Translational Research Imaging Center; RTT = Round Trip Time; UCSF = University of California San Francisco

There were no issues requiring on-site device or robot troubleshooting during navigation. No manual intervention was needed, and there were no instances of tool buckling or device failure.

DISCUSSION

This study aims to bridge the gap between reports of isolated endovascular maneuvers, such as two-axis guidewire control performed remotely (Patel et al., 2019), and the comprehensive needs of clinical practice. It demonstrates the technical, logistical, and connectivity feasibility of implementing remote robotic neurointervention from multiple remote locations under real-world time constraints, with all procedures completed in a single afternoon.

A significant obstacle to remote intervention has been the absence of a robotic system capable of performing an entire procedure without manual assistance following vascular access. While in a clinical setting on-site staff will continue to have a role in robot setup, patient support, anesthesia and femoral access, for remote intervention to be effective and expand access to care it is essential that there is no need for an on-site neurointerventionalist and no need for manual intervention following vascular access. The remote user should be able to do robotically what they would do manually in the event of complications. In this study, once femoral access was achieved by the on-site technician, tool control and navigation from the RCFA to the MCA was completed by the operator entirely remotely and without bedside intervention. Future iterations will allow remote deployment of end-effectors and management of complications allowing a range of procedures to be completed with no on-site specialist.

The intuitive nature of the control system is evidenced by the fact that navigation from an origin vessel (e.g., aortic arch) to a destination vessel (e.g., LCCA) was unsuccessful on the first attempt only three times. Operators did not identify any challenges in navigation as a result of the lack of tactile or force feedback. Results were consistent across operators in terms of success of navigation from Femoral access to the MCA without bedside assistance, episodes of tool tip contact with the vessel wall, total procedural times and duration of time spent on different aspects of the procedure.

Neurointervention demands precise, real-time manipulation of endovascular tools, making optimal network performance essential for the safety and success of remote procedures. Inadequate network performance can result in connection loss and episodes of unsafe latency, potentially causing procedural delays, treatment failures, and, in the worst cases, vascular injury. Unsafe latency refers to the threshold beyond which a patient's risk of complications or treatment failure increases due to prolonged RTT. The determination of a threshold value for unsafe latency continues to be an area of research. Legeza et al. (2022) found in their study of simulated network latencies that a latency of 400ms was perceptible by operators but still considered acceptable using an institutional network connection in a control room next to the interventional suite in a porcine model. In a first-in-human study, Patel et al. (2019) showed successful angioplasty and stenting of coronary lesions in five patients by a remote operator 20 miles away after the coronary ostium had been catheterized by a local operator.

Over the 20-mile distance, they reported a mean lag time of 53 ± 11ms, and the operator rated the response time and device control as satisfactory or extremely satisfactory. Other groups have demonstrated that network latencies ≤250ms are not noticeable to the operator and do not impact performance (Rayman et al. 2006; Xu et al. 2014; Madder et al. 2020).

Determining unsafe latency is complex, as it can vary significantly throughout a procedure. Safe latency depends on various factors, including the speed of tool movement, the physical characteristics of the tools used, and the characteristics of the navigated vessels. For instance, the safe latency for controlling a stiff guidewire in the MCA differs from that for controlling a catheter in the aorta. To address this variability, in this study unsafe latency was defined by considering the scenario most susceptible to complications in the event of prolonged latency—specifically, controlling a stiff guidewire abutting the MCA wall. The minimum time needed for the guidewire to generate enough force to cause vascular injury while traveling at its maximum speed defines the latency threshold.

In this study, the unsafe latency threshold was set at 150ms. Robust preoperative connectivity checks were conducted for at least one week before remote use to ensure reliability. Protocols were established to manage prolonged latency and loss of connection intraoperatively, prohibiting tool insertion and contrast injection when the unsafe latency threshold was breached, or connection was lost. None of the operators reported noticeable lag. The latency threshold was violated twice using a connection from 2,487 miles away via public Wifi. These violations were mitigated by the aforementioned safety mechanisms by momentarily preventing insertion of devices until latency returned to an acceptable level. This momentary lockout was not noticeable by the user as the durations of prolonged latency were only 200ms and 804ms. As data transfer is bidirectional, the outcomes from remote connections to a robot in Los Angeles can be generalized to a remote connection from a specialist at a center such as UCLA to robots in smaller centers where access challenges are likely to be more acute and connectivity may be more akin to the public Wifi points used by operators in this study. There were no issues related to integration of the RR software with the UC system and firewalls or other permissive IT elements were dealt with.

In addition to the technical barriers to implementation of remote intervention such as device functionality and latency that this paper addresses, a number of overlapping clinical, practical and legal challenges will need to be addressed for remote robotic Neurointervention to achieve widespread clinical adoption (Chandra et al. 2025). Responsibility and liability for connection related risk including latency and connection failure is a particularly novel challenge, however the outcomes of this study suggest that, with an appropriately designed robotic system, connectivity sufficient for remote intervention is feasible. The risk of connection failure or latency can be further mitigated by sustained connection testing, safety controls that are automatically engaged if poor connectivity is detected, and fall-back workflows in the case of complications, however there will likely be some residual risk of connection or device failure. This risk does, however, need to be balanced against the risk of not providing intervention at all or providing a substandard intervention after transfer, which the authors consider will likely be substantially greater in most instances. In addressing other issues, such as audiovisual communication with onsite staff, licensing of software across systems, patient consent and remote operator liability, lessons can be learned from existing remote services including tele-stroke services and the remote radiography practices, although clear processes will need to be developed to allow time-critical remote teleoperation. While these challenges are material, and will be the subject of additional research and publication, the authors consider that in each case these challenges are solvable and the potential benefits to remote tele-operation are significant enough to justify the development of new processes to allow its widespread implementation.

Limitations

This study has several limitations, both in the robotic system examined and its design. Regarding the robotic system, users operated it from a variety of personal laptops, which introduced audio-visual constraints due to limited screen sizes. This issue has since been resolved and future studies will utilize defined, consistent operator hardware including a consistent minimum screen size. In real-world applications, effective communication between the remote operator and the anesthesiologists, nurses, and technologists, who may have limited experience with the procedure, will be critical.

In other surgical fields, machine learning of procedural steps has proven beneficial for education and assessment (Humm et al. 2023). Future developments could integrate AI to analyze the clinical environment and patient condition, alerting team members to workflow requirements (Khan et al. 2021).

The study did not demonstrate the deployment of an end effector, as it was an early-stage prototype, and reliable end effector deployment had not yet been tested. Remote end-effector deployment is critical if remote robotic neurointervention is to be successful and subsequent iterations of the system tested have addressed this requirement. Additionally, the system's ability to handle complications, such as coiling in a remote setting, was not assessed—though again this has been addressed in subsequent advancements.

In terms of study design, a notable limitation was the omission of setup time measurement, a crucial factor in assessing the system's feasibility and adoption. For the system to be viable, the setup time combined with procedural time must match or improve upon manual methods. Moreover, the use of a single silicone model limits the generalizability of the results to different clinical scenarios – testing in different anatomy and clinical settings will be the subject of future research and publications. Sterility of the catheter and robot system was also not considered for this study, although the system is compatible a sterile environment and its catheters have since undergone sterilization validation. Tool tip contact with the vessel wall was assessed visually and force of contact was not measured. Reliable preoperative connectivity information was only measured between two sites. In clinical settings, operators should receive comprehensive training and use designated computing equipment, including a specific computer and monitor setup, connected via a wired ethernet connection tested for reliability.

Finally, the study did not include a control group to compare robotic versus manual performance. The study's intent was not to compare these two approaches but to demonstrate the feasibility of remote robotic technology. Addressing these limitations in future research will enhance the feasibility and adoption of robotic neurovascular interventions in both clinical and remote environments.

CONCLUSIONS

The project highlights the successful integration of a robotic system into a modern neuroangiography suite and demonstrates the ability of multiple remote specialists to control the robot within a condensed time frame. Achieving successful remote robotic intervention necessitates a functional robotic device capable of performing an entire procedure without bedside intervention, a secure, reliable internet connection and an approach to monitoring and managing latency. This study effectively addresses these key challenges and, while a number of other hurdles remain before widespread clinical adoption is realized, its outcomes underscore the feasibility and potential of remote robotic neurointervention.

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