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Abstract

Regional rural medical school campuses offer many opportunities for medical students to gain more hands-on experience, have more direct interaction with attending physicians, and cultivate a deeper understanding of challenges and opportunities specific to rural medicine. Some specialty services such as neurology are not always readily available at these small regional campuses, and telemedicine technology can be a valuable tool to address this need. We report the implementation of teleneurology stroke consultation services as part of the third-year neurology clerkship at a regional medical school campus. We analyzed daily clinical notes and student satisfaction surveys. Students saw many common presentations of cerebrovascular events as part of a multi-disciplinary care team. While students followed patients through their hospital course they were provided effective instruction by remote stroke neurologists. All students strongly agreed that telemedicine was a positive component of the clerkship. We conclude that teleneurology is effective in providing inpatient neurology clinical exposure, especially when remote attendings have a strong screen presence and are enthusiastic about teaching. We believe these findings could be useful to other campuses considering similar teaching methods, as innovations in telemedicine continue to address challenges in medical education and clinical care.

Introduction

Telehealth is the broad term that describes the vast range of technology used to connect healthcare providers to patients and other providers. Telemedicine is a more specific term referring to the provision of medical care remotely through electronic communication between a health care provider and a patient. The use of telemedicine dates back to the 1940s, however, the advancement of technology has propelled this field forward with growing interest.[1,2] Increasing internet speed and access along with widespread use of technological devices, such as smartphones and computers, in rural areas has opened the door for telemedicine to meet challenges regarding access to primary and specialty medical care.[3] In addition to its application in addressing physician shortages in the rural setting, telehealth has become an invaluable tool in the fight against the novel coronavirus disease (COVID-19). Not only has the use of telemedicine increased exponentially, we have also witnessed a surge of interest in telemedicine by the United States population.[4]

Neurology is a specialty that has a significant provider shortage in comparison to the growing population in need of these services.[5] This is particularly evident in

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rural regions of the United States where there are large differences in rural-urban neurologist density.[2] An effective solution in many of these underserved regions comes in the form of telemedicine or, specifically, "teleneurology". Teleneurology is a specialized form of telemedicine where a neurologist sees patients remotely, whether it is in the outpatient setting for chronic neurologic conditions or for inpatient acute care.[6] This approach utilizes synchronous communication methods via live audio and video to provide comprehensive neurology care to a rural patient population.

Small regional medical school campuses have many benefits, including one on one teaching, carrying responsibilities of an intern, and collaborating with many members of the care team. This environment provides students with unparalleled hands-on patient and care team experience, which later contributes to a vital skill set utilized daily as a resident physician. Despite the many advantages of this training environment, there are challenges for regional campuses. One such challenge is decreased availability of specialty providers (i.e. neurologists, dermatologists, rheumatologists) in the rural setting, resulting in minimal on-site training opportunities with these specialists.

The team of physicians serving our rural medical campus included neurology until 4 years ago. The lack of a neurologist presented a gap in the required neurology clinical experience for the rural track medical students. One possible solution was to have the rural-based students travel back to the main campus university hospital, located 160 miles away, to complete this rotation. Returning to the urban environment for the 4-week rotation was not ideal due to the student housing obligation, disruption of rural-focused training,[7] and the interruption of longitudinal student experiences including regular small group teaching sessions and providing care for longitudinal patients at the weekly student-run free clinic.

It was ultimately decided that the rural-based students would commute an hour away to a neurologist's office 2 to 3 days a week, and on the days students did not commute, they spent time with sleep medicine and inpatient geriatric psychiatry on the rural campus. These clinical experiences provided opportunities to learn about the presentation and management of chronic plus outpatient neurological diseases including insomnia, narcolepsy, restless legs syndrome, Parkinson's disease, multiple sclerosis, other neurodegenerative diseases, dementia, and delirium. The adapted neurology curriculum produced comparable student performance on shelf exams and student feedback when compared to main campus students.

Despite providing rural students with adequate chronic and outpatient neurology clinical experience, there remained a significant learning gap in acute inpatient neurology care. In the spring of 2019, the hospital which hosts the medical campus began the process of implementing teleneurology stroke consultation with full-service care beginning in summer 2019. Not only would this address an evident need for acute neurology care in our rural area, but also it held significant potential to meet the educational need for the rural medical students.

A literature review revealed no publications about student educational outcomes or opportunities involving telemedicine used in rural medical student training sites. Most research published to date emphasized rural inpatient outcomes in acute teleneurology or telestroke services[2,5,6,8,9,10] or focused on the need for additional neurology resident or medical student training on general telemedicine practices.[11,12,13,14,15,16] An essay was recently published describing the anecdotal experience by the first student to participate in this learning experience.[17] This study describes in detail the results of the first semester of the new teleneurology teaching service, including student evaluations and the clinical characteristics of the patients seen. We hope this report may serve as a guide for other regional medical campuses considering similar teaching methods.

Methods

Our regional medical campus is located in a Madisonville, Kentucky, which has an approximate population of 20 000. This campus is the primary clinical training site for 14-16 allopathic third- and fourth-year medical students who move here after

completing the first 2 years of basic science education at the main urban campus 160 miles away. Students who have a proven affinity for rural settings are assigned at the time of admission to medical school to this campus where they have the opportunity for unique, first-hand clinical experiences with rural and underserved patient populations. These students complete required third- and fourth-year clerkships and electives in this rural setting and work closely with their respective attending faculty, typically in a one-to-one apprenticeship model. Academic outcomes including clerkship shelf exams and step 2 USMLE scores are comparable to those of main campus students.[18] One of only 2 published multivariate analyses of predictors of rural practice showed that participation at this campus was the strongest predictor even when controlling for the usual variables of rural upbringing and family medicine specialty choice.[19]

Design of Telestroke Teaching Service

The inpatient teleneurology care team began full-service acute stroke care at our regional medical campus in August 2019. The students reported here rotated with the team during the winter of 2019/2020 and then after the gap necessitated by the pandemic another student rotated in the fall of 2020. Teleneurology care was provided via live communication using a standard healthcare cart, HP all in one central processing unit (CPU) and monitor and a standard 20x zoom remotely controlled camera (Figure 1). This system used the hospital password protected secure wireless internet connection and allowed the teleneurologist to interact with patients and their families from his or her urban referral hospital location in a synchronous manner. This design also facilitated close synchronous interaction and communication with the comprehensive rural neurology care team, including a Physical Therapist (PT), Occupational Therapist (OT), nursing staff, speech therapist, and the rotating medical student. A dedicated nurse practitioner (APRN) was added to the team in the spring of 2020. The medical student made daily rounds with the inpatient neurology team 2 to 3 days per week for the duration of the 4-week rotation and followed their stroke patients between commuting days to the outpatient neurologist. There were no audio or visual technical diffuclties. However, in the case of technical difficulties, all members of the team have direct access to the neurologist and IT support by telephone.

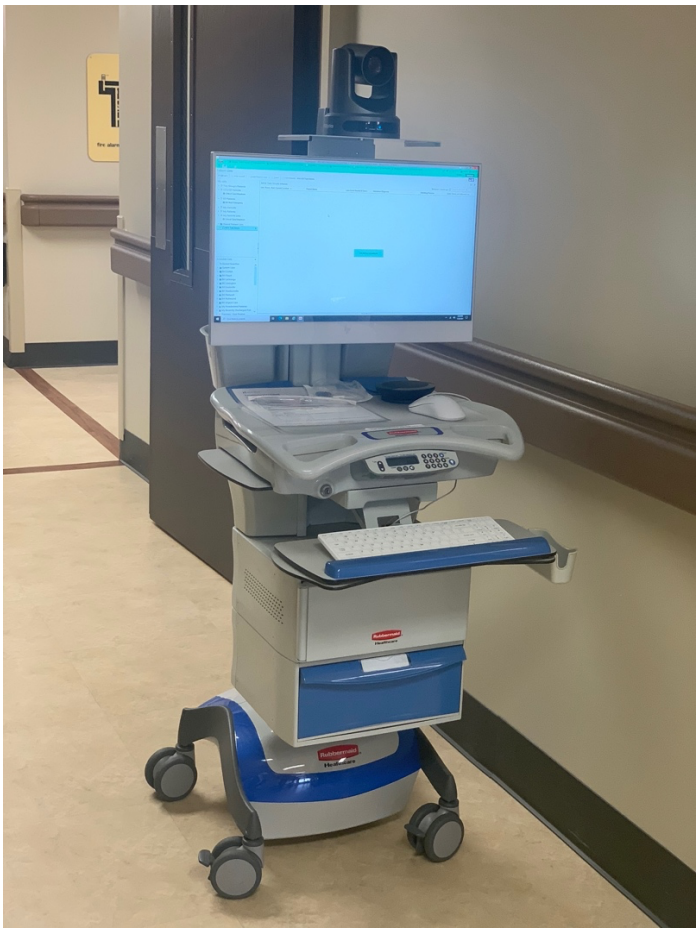

Figure 1. [Teleneurology cart setup].

When a patient presented to the Emergency Department (ED) or had an acute change suspicious of stroke while hospitalized for another reason, a “code stroke” was called within the hospital. This resulted in a rapid cascade of events where the on-call neurologist was notified promptly. Often, the rotating medical student (or nurse practitioner) was the first member of the team to assess the patient following a code stroke. The student was often responsible for transporting the teleneurology robot to the ED or patient room. This process allowed for stroke patients to be seen and evaluated within 30 minutes of the “code stroke” by the on-call neurologist.

When the attending neurologist appeared on screen, he or she began their assessment and followed

typical stroke protocol. If a cerebral vascular event (CVE) or transient ischemic attack (TIA) not requiring neurosurgery was suspected, the patient was admitted to the hospitalist service in the Critical Care Unit (CCU) and followed by the teleneurology team. If tissue plasminogen activator (TPA) was appropriate, it was administered in the CCU. Patients with a clinical presentation and imaging consistent with hemorrhagic stroke were promptly evaluated and transported to the neurosurgical-capable facility one hour away.

Each morning the neurology care team met in the ICU conference room for morning report to review and discuss new and follow-up patients. The medical student completed pre-rounds on all patients before morning report, completing a full history and physical examination. The student documented his or her findings with a detailed teleneurology daily record note. Any updates on the patients were presented during morning report. Team members from PT, OT, nursing, and speech contributed their discipline specific updates for each patient.

When morning report was finished, formal rounds began. The team went to each patient room and the neurologist, via the robot, conducted a focused history and neurological exam. The medical student performed most of the neurological exam. This not only allowed the neurologist to see the exam findings, but also provided an opportunity for one-on-one instruction of the medical student. If there were no new consults, the remote neurologist spent 30 to 90 minutes teaching about topics relevant to the patients seen that morning. Students reviewed recent publications and articles related to acute neurology care as recommended by the remote faculty. In addition to this supplemental teaching, rural track students participate in the same virtual lecture series, readings, and online patient case materials as main campus students. The required curriculum covers a broad range of acute, chronic, inpatient, and outpatient neurologic topics.

The medical students were responsible for completing daily record notes for each patient seen with the neurologist. This note template, developed by the students, served as a running record of each patient with distinct sections as shown in Table 1. The student completed 2 notes for each patient. The student version was completed as soon after admission as possible and was used for later review with the outpatient neurologist. The second version of the note was for research purposes and included the final summary of imaging results and the assessment and plan of the remote neurologist, which we report here. The student version was considered a catalyst for active learning and allowed for guided practice with critical thinking in the setting of acute neurology care. Immediate feedback on the draft student notes was provided by the on-site nurse practitioner.

Table 1. Daily Record Components
1. Demographics (age, sex, race)
2. Chief complaint
3. Date presented to ED and last time known well
4. Presenting symptoms
5. Medical history, Surgical history, Social history
6. Current medications
7. Allergies
10. Review of symptoms
11. Vitals and Physical exam (neurology exam)
13. Diagnostic studies (labs, imaging, tests)
14. Abnormal results
15. Assessment and Plan

In addition to inpatient clinical experience, medical students commuted 2 to 3 times per week to an outpatient neurology office located one hour away. In this setting, students learned common outpatient complaints and management protocols. Students saw patients in the office where they obtained patient history, performed physical examination, developed an assessment and plan, and presented to the in-person neurologist. Students also wrote notes on patients seen. In addition, students observed common office procedures like electromyography (EMG) and Botulinum toxin injection. The neurologist reviewed the student version of the inpatient daily stroke notes and provided additional feedback to the student.

We summarized demographic and clinical information using frequencies and percentages, with the patient population of 49 as the denominator. Comorbidities were obtained using the patient

problem list as shown in the electronic medical record (EMR) and re-checked using the patient medication lists from EMR. The presenting complaints were the chief complaints provided by the patient on arrival at the emergency department. These were obtained directly from the patient chart or by talking directly with the patient. We measured student satisfaction by having each rotating student complete a series of surveys at the conclusion of their neurology clerkship. The surveys evaluated student satisfaction with the overall rotation experience, as well as an evaluation of teleneurology attending performance and teaching. Direct individual feedback was not sought from patients, but the tele-stroke team leaders provided comments specific to student involvement.

Results

Data from 4 third-year medical students was included in this study. A total of 49 neurology patients were seen by the medical students. The patient population seen by students is described in Table 2 and patient outcomes outlined in Table 3.

Table 2. Patient Population	
Number Patients	49
	Mean (Range)
Age	69 (23-93)
	Frequency (%)
Female	28 (57.1%)
White	48 (98.0%)
Black	1 (2.0%)
Comorbidities	
Hypertension	44 (89.8%)
Hyperlipidemia	44 (89.8%)
Tobacco Users	21 (42.9%)
Diabetes Mellitus Type 2	21 (42.9%)
Coronary Artery Disease	13 (26.5%)
Atrial Fibrillation	8 (16.3%)
Presenting Complaint	
Weakness	29 (59.2%)
Dysarthria	21 (42.9%)
Numbness	8 (16.3%)
Confusion	8 (16.3%)
Visual Field Deficits	7 (14.3%)
Dizziness	7 (14.3%)
Ataxia	5 (10.2%)
Headache	5 (10.2%)
Fall	3 (6.12%)
Facial Droop	2 (4.08%)

Table 3. Patient Outcome Final Diagnosis	Frequency (%)
Infarct	29 (59.2%)
Transient Ischemic Attack	8 (16.4%)
Deficits from prior Cerebrovascular Accident	2 (4.1%)
Complex Migraine	2 (4.1%)
Hypertensive emergency	2 (4.1%)
Metabolic Encephalopathy	2 (4.1%)
Radiculopathy	1 (2.0%)
Conversion disorder	1 (2.0%)
Transient Global Amnesia	1 (2.0%)
Hypoxia (Pneumonia)	1 (2.0%)
Hospital Course	**Mean (range)**
Length of Stay in acute bed	2 (1-6)
Length of Stay in inpatient Rehabilitation	14 (0-23)
Final Disposition	
Home	24 (49.0%)
Home with Occupational Therapy/Physical Therapy /Speech	17 (34.7%)
Skilled Nursing Facility	6 (12.2%)
Transfer during initial hospital stay	2 (4.1%)

Student evaluation data and comments are summarized in Table 4, along with staff comments. The survey responses were on a Likert scale (strongly disagree -1, disagree -2, neutral 3, agree- 4, strongly agree-5). We combined all student responses to provide the mean response and range.

Table 4. Student Evaluation of the Project	Mean response (range)
Technology was useful for learning.	5 (5)
Remote faculty observation of my exam was helpful.	5 (5)
Interdisciplinary approach was optimal for learning.	5 (5)
Faculty teaching was effective.	4.92 (4-5)
Student's role was appropriate for learning.	4.88 (4-5)
The experience was organized, and expectations were communicated.	4.31 (2-5)
Stroke daily record was useful for learning.	4 (2-5)

Student/Staff Comments

"Faculty 1 had great screen presence and was able to keep everyone involved and interested"

"Faculty 3 had a great screen presence and answered all questions by patients and families."

"Faculty 4 had a very positive presence and in no way over-critical to students."

"Faculty 5 was very approachable and understood the knowledge base of a typical third year student. Faculty 5 recommended several articles which were beneficial with shelf studying. He reviewed 2 articles with me daily and asked great review questions."

"Faculty 3 was extremely enthusiastic about teaching, gave me lectures on stroke, but also other neuro topics that would be helpful for the shelf. Faculty 3 also gave me feedback with each patient, so I knew exactly how I needed to improve. Wonderful teacher."

"Faculty 2 did not attempt to teach. I am not sure if he was unaware that he was supposed to teach. He did not attempt to bring me into each patient's care but did passively allow me to perform the neuro exam in place of the nurse."

"Faculty 1 is very knowledgeable and ecstatic to teach, joy to learn from. Can't speak highly enough."

"Faculty 1 talked through abnormal MRIs, MRAs, CTAs and CT scans and explained when to use with vs without contrast CTs and explained the difference between T1 and T2."

"Faculty 1 expects students to take part in neuro examination on rounds, present patients, and be an active member of the care team."

"Faculty 3 actively included me in new consults, and I was able to see and perform full neuro exams in the ED."

"Faculty 4 asked my input and inquired about my assessment and plan."

"As the first medical student to participate in the teleneurology curriculum I felt like we were still trying to work out the details of how things would work in reality vs. in theory. It did not take long to work out most of those factors. I found the addition of teleneurology inpatient curriculum very helpful to my overall learning of neurology as a discipline. I felt that this portion of the rotation specifically helped me grow in my presentation and physical examination skills, as well as my abilities to work with a large multi-disciplinary team."

"During my rotation, the neurology faculty schedule was in flux and changing constantly (making it hard to get in a routine). Otherwise, neurology via telemedicine has been incredibly enriching. I met all required diagnoses quickly, improved my presentation skills, and perfected my physical examination skills."

"Student involvement has been a positive addition to the team as a whole. Students are learning how to educate patients on stroke care and prevention. In addition, they will be able to identify high risk patients and risk factors. They are a valuable addition to the entire team." – APRN

"Overall, patients are positively impacted by students on the rotation and are extremely receptive to student rotators taking an active role in their care." - APRN

"Having medical students on the teleneurology service was so refreshing and added a new level of intellectual stimulation. The students bring a curiosity and passion for working with the patients. They allow for the entire team to be reminded and refreshed on basic science components through their questions." - PT

"Patients are more than accepting of having medical students as a part of their care team. The students spend quality time listening to the patients, talking with them, and helping to educate the patient. The degree to which students are able to spend with each patient allows for them to act as a valuable liaison between the patient and the team." - PT

With the adapted neurology curriculum for the study time period, students scored 1.5 points higher on the clinical evaluation than did the main campus students and 2.6 points higher on the shelf exam. In this patient group, all but 2 patients received all acute neurologic care and were medically managed within the rural hospital. None of the patients included in this group received thrombolytics because they presented outside of the required time window.

Discussion

The primary goal of implementing teleneurology into the clerkship curriculum was for each student to participate in full scope neurology clinical care. The new curriculum allowed for continued outpatient

experiences, and patient-centered, multidisciplinary approaches to inpatient acute stroke care. The addition of inpatient teleneurology curriculum was well accepted by all participating students. Our survey indicated that all 4 medical students responded "strongly agree" when asked if they were satisfied with telemedicine as a part of their learning experience.

Weakness was the most common presenting symptom of patients seen followed by dysarthria, numbness, and confusion. All of these are common and important presentations for students to understand. Overall, the most frequent diagnosis was cerebral infarction, followed by transient ischemic attacks, and non-stroke diagnoses. Medical students were able to follow patients who initially presented with symptoms suspicious for CVE until diagnosis and disposition. Students were encouraged by telemedicine attendings to create a differential diagnosis, assessment, and plan for each patient. The fact that 95.9% of our patients were able to be cared for in our community hospital where they may know staff and where their family can easily visit speaks to the value to our patient population. The teleneurology service also keeps revenue for acute care in our local hospital, an important concern for all community hospitals.

Each faculty received mostly high marks on student evaluations. Student surveys indicated that remote faculty teaching was considered effective by all medical students. The medical students worked with and evaluated 5 teleneurology physicians. Students commented on certain faculty members taking extra time to explain key neurology concepts and review diagnostic imaging, including information on when to use specific forms of imaging in patient scenarios. This unique form of communication allowed for faculty to provide lectures on stroke, review up to date, evidence-based articles, and give feedback to students on physical exam and topics discussed.

Faculty screen presence was specifically noted by students and contributed to the overall learning experience. In this context, we define screen presence as the ability to connect with and engage the person (colleague, care team member, patient, patient family, or student) with whom one is communicating via telemedicine robot or live video conference. This attribute includes speaking distinctly and allowing for the audio delay to avoid talking over someone. It also includes pausing to recognize persons at the other end and giving them opportunities to contribute without having to interrupt. Student feedback suggested that many of the faculty demonstrated quality screen presence that in turn enhanced the patient's experience and the learning for students. A positive screen presence resulted in improved patient and family engagement by the neurologist and gave the medical student the confidence to perform the neurologic exam and ask questions.

In addition, participation in the multidisciplinary care team provided students with structure and purpose. Our survey indicated that students gained valuable skills by working with other healthcare disciplines on a team. This is an important skill for future physicians that cannot be taught in traditional didactics. Through patient presentation during morning report, medical students were able to demonstrate active knowledge of each patient case. Medical students saw new consults, formulated their own assessments and plans, and received important constructive feedback from teleneurology faculty. In addition to pre-rounds each morning, by acting as the "hands" of the remote neurologist, the medical student held an active role in patient care. Our survey indicated that all medical students were observed directly by the neurologist while completing the full neurology examination.

Enthusiastic interest in teaching, thoughtful screen presence, and high expectations for the student as an essential part of the team were faculty characteristics that resulted in positive learning outcomes for students. Students noted that direct feedback on presentation and exam skills added to the overall educational value.

Overall, the staff who were surveyed remarked that medical students were a positive addition to the care team, and they noted that patients were very accepting of having students be an active part of their care. Most patients appreciated the extra time medical students spent with them and felt that their concerns were heard based on staff observation. Patients were not surveyed, however, based on student and faculty observation the patients and their

families were very receptive to this method of care. The live communication between the patient or family and the teleneurologist was smooth and without delay, almost as if the neurologist were physically in the patient room.

Study Limitations and Strengths

Our study included only 4 students. Two additional medical students were expected to participate during the study period, but the COVID-19 pandemic caused a nation-wide disruption in clinical training for third- and fourth-year medical students. However, the strong similarity of feedback from all 4 students suggests that they are representative of the larger group. The exception was the one student who felt that the organization and the daily stroke record needed improvement. Further discussion with this student showed that many of the details of the teleneurology team were being worked out at the time of her rotation, and the organization of the overall rotation improved as she progressed over the 4-week period. She also provided valuable feedback for improving the daily stroke record to maximize efficiency and learning potential. Lack of continuity between student and remote faculty was cited as an issue by some students. More continuity is always preferred, but the same discontinuity is encountered on most university teaching services, where the team attending may change weekly or even more frequently depending on their other responsibilities.

Although students became very familiar with the requirements and contraindications for thrombolytics in acute stroke symdromes, they had no experience following patients who received them. At our hospital during this time period, very few patients presented during the appropriate time window. This is largely thought to be due to a lack of understanding of common presenting stroke symptoms within the community and the community is still learning about these new capabilities in the hospital. The hospital system is actively trying to educate the community on common signs and symptoms of stroke through informative videos online and radio broadcasts. It was important for students to learn of these obstacles. The hospital is not yet considered a certified stroke center, and the closest certified stroke center is located 48 miles away in Evansville, Indiana.

Identified strengths of the experience include preceptor willingness and enthusiasm for teaching which added to the students' learning experience as preceptors provided excellent feedback and established the student as an integral part of the stroke care team. An important benefit of this process was the ability of the student to participate directly in a multidisciplinary care team. This allowed the student to develop communication and team building skills necessary for quality patient care and success in their future residency training and career.

Conclusion

We conclude that participating students were satisfied with the teleneurology rotation experience and enjoyed learning from remote faculty. Students felt that their learning was more comprehensive with the inclusion of teleneurology in the inpatient setting. In addition, students had an increased confidence in conducting the neurological examination and collaborating as a part of a multidisciplinary team at the conclusion of the rotation. Students expressed increased understanding of telemedicine services and its many uses within the inpatient and outpatient settings. Students expressed overall satisfaction with the daily record as a learning tool to record history, physical exam findings, assessment, and plan.

Students were exposed to a wide variety of common inpatient neurological complaints, diagnostics, and management protocols. All students completing the neurology rotation at our regional campus were able to see all required diagnoses in-person, and the addition of teleneurology technology greatly assisted in student engagement in the direct care of patients with suspected strokes. Telemedicine holds significant promise for medical student education and facilitating access to care for rural and other underserved patient populations. Further research and innovation are needed to optimize the effective use of this technology.

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