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5G remote robotic-assisted transcervical thyroidectomy: the first case report in the world

Shaojie Wu[1†], Nan Wu[1†], Yongqiang Wang[2], Ren Jing[1], Yang Wu[1*] and Shijian Yi[1*]

Abstract

Background The incidence of thyroid malignancies is increasing due to the development of detection techniques. The demand for aesthetics and precision has led surgeons to innovate in surgery, and with the development of 5G technology, telesurgery has become a reality.

Case presentation We present the case of a 37-year-old woman with a physical examination that revealed a nodule of about 0.5*0.5 cm in size in the left lobe of the thyroid gland, with preoperative puncture pathology suggestive of papillary carcinoma. A 5G remote robotic thyroidectomy was performed from Shanghai to Shenzhen.

Conclusions We believe this paper reports the world's first 5G tele-robotic-assisted transthoracic breast approach thyroidectomy.

Keywords Robotic-assisted surgery, Remote surgery, Transcervical thyroidectomy, 5G.

Background

Thyroid cancer ranks as the ninth most prevalent malignancy worldwide, with a particularly high incidence among adolescents and adults under 40 years of age [1, 2]. Notably, the past four decades have witnessed a dramatic 313% surge in thyroid cancer incidence, primarily attributable to the widespread adoption of advanced imaging modalities and the implementation of fine-needle aspiration biopsies, which have significantly enhanced diagnostic capabilities [3]. Fortunately, mortality from thyroid cancer remains low, at only 0.5 deaths per 100,000 people per year, varying by histology and stage of disease, and in the best-case scenario a patient's 5-year relative survival rate can be as high as 98.5% [1, 4]. Furthermore, epidemiological data indicate that the majority (54%) of well-differentiated thyroid carcinomas are associated with a low recurrence risk and can be effectively managed through surgical intervention alone [5, 6]. However, traditional open thyroidectomy, while effectively exposing the gland and allowing for meticulous suturing, leaves noticeable scars on the patient's neck. Given that most patients are young women, various minimally invasive techniques have emerged to avoid scars that could affect aesthetics [7].

Compared to conventional thyroidectomy, robotic-assisted surgery offers numerous advantages, including improved cosmetic outcomes, reduced perioperative

†Shaojie Wu and Nan Wu contributed equally to this work.

*Correspondence:
Yang Wu
szwy1022@163.com
Shijian Yi
yishijian1969@szu.edu.cn
[1]Department of Thyroid and Breast Surgery, South China Hospital, Medical School, Shenzhen University, No.1, Fuxin Road, Longgang District, Shenzhen 518116, P. R. China
[2]Department of Experiment & Research, South China Hospital, Medical School, Shenzhen University, Shenzhen 518116, P. R. China

complications, early access to adjuvant therapy, and less psychological impact [8, 9]. Furthermore, robotic-assisted surgery effectively addresses several technical limitations inherent in endoscopic procedures, particularly the constrained instrument maneuverability and unstable two-dimensional visualization that often challenge surgeons during conventional endoscopic operations. These technological advancements, coupled with improved ergonomics and enhanced surgical precision, have contributed to the growing global adoption of robotic-assisted thyroidectomy [10].

Receiver-side latency and network instability have long have been major obstacles to real-time telesurgery. However, the recent generation of 5G (fifth-generation wireless systems) network technology excels in speed, low latency, and high bandwidth, making remote surgery a reality with the advent of fifth-generation wireless systems [11]. Notably, to the best of our knowledge, this investigation represents the first documented case series of 5G-enabled telerobotic-assisted thyroidectomy utilizing the transthoracic breast approach in medical literature. This study not only provides a comprehensive description of the surgical technique but also evaluates short-term oncological outcomes, thereby establishing a valuable framework for future implementation and standardization of remote surgical procedures.

Case presentation

A 37-year-old Chinese female was admitted to the hospital with an 18-day-old left-sided thyroid nodule found on physical examination. The patient was previously healthy and had no history of specific chronic diseases. Initial physical examination revealed a firm, well-demarcated nodule measuring approximately 0.5 × 0.5 cm in the left thyroid lobe, demonstrating restricted mobility without palpable tenderness. Cervical lymph node examination was negative for adenopathy bilaterally. Routine laboratory investigations were within normal limits. Diagnostic imaging, including thyroid ultrasound performed on August 5, 2024, identified a solid hypoechoic nodule (6.0 × 5.0 × 5.2 mm) in the left thyroid lobe, classified as TI-RADS 4a, with no suspicious cervical lymphadenopathy. Subsequent ultrasound-guided fine-needle aspiration biopsy conducted on August 12, 2024, yielded a histopathological diagnosis of papillary thyroid carcinoma (Bethesda Category VI). Complementary diagnostic evaluation through contrast-enhanced neck CT demonstrated a 4 mm hypodense lesion with irregular margins in the left thyroid lobe. Preoperative laryngoscopic examination revealed normal vocal cord mobility and tracheal anatomy.

The comprehensive preoperative assessment revealed no surgical contraindications. Following detailed consultation regarding the diagnosis, proposed surgical intervention, and potential risks, the patient and her family provided informed consent through signed surgical and clinical research consent forms.

Surgical technique

This study utilized the Chinese robotic system, the Tumai MT-1000, for thoracoscopic and abdominal surgeries. The s No. 2 robotic arm was equipped with an 8 mm grasping forceps, the No. 3 arm with a 3D high-resolution endoscope, and the No. 4 arm with an ultrasonic scalpel.

The primary surgeon, Dr. Yi, was located at the Shanghai Minimally Invasive Surgical Robot Center, while the backup surgeon, Dr. Wu, was in the operating room of the South China Hospital affiliated with Shenzhen University. Both surgeons possessed certification for robotic surgery.

After successful intubation and general anesthesia, the patient was positioned supine with legs spread apart, a pillow placed under the shoulders, and the head extended. Two 9 mm incisions were made 1 cm above the bilateral areolae, and a 12 mm transverse incision was created at the midpoint of the line connecting both nipples. An additional 5 mm auxiliary incision was made in the left axillary region. Through the 12 mm incision, the subcutaneous tissue was dissected to the sternoclavicular joint, and three trocars (12 mm, 9 mm, and 9 mm) along with the camera were placed through the incisions. The auxiliary incision in the left axillary region was utilized for an additional smoke evacuation device (Fig. 1). Following connection to CO2, the Tumai MT-1000 thoracoscopic and abdominal surgical system was set up. The robotic arms (2nd, 3rd, and 4th) were connected from right to left. After successfully establishing a 5G remote surgery connection between the Shanghai Minimally Invasive Surgical Robot Center and the operating room at the South China Hospital, Dr. Yi performed the surgery remotely from Shanghai. Using the ultrasonic scalpel, the subcutaneous loose tissue was dissected along the surface of the sternohyoid muscle, extending from the thyroid cartilage above to the suprasternal notch below, and laterally to the outer edge of the sternocleidomastoid muscle. The midline of the neck was incised, and the anterior neck muscles were separated. Dissection was performed between the thyroid fascia and the intrinsic fascia to expose the bilateral thyroid glands. The ultrasonic scalpel was used to incise along the right side of the thyroid isthmus, exposing the trachea. The left thyroid lobe was retracted inward while blunt and sharp dissection revealed its lateral margin. The middle vein was cut and ligated, followed by ligation of the upper and lower arterial branches as the left lobe was retracted downward and upward, respectively. The left thyroid lobe and isthmus were excised together with the mass using

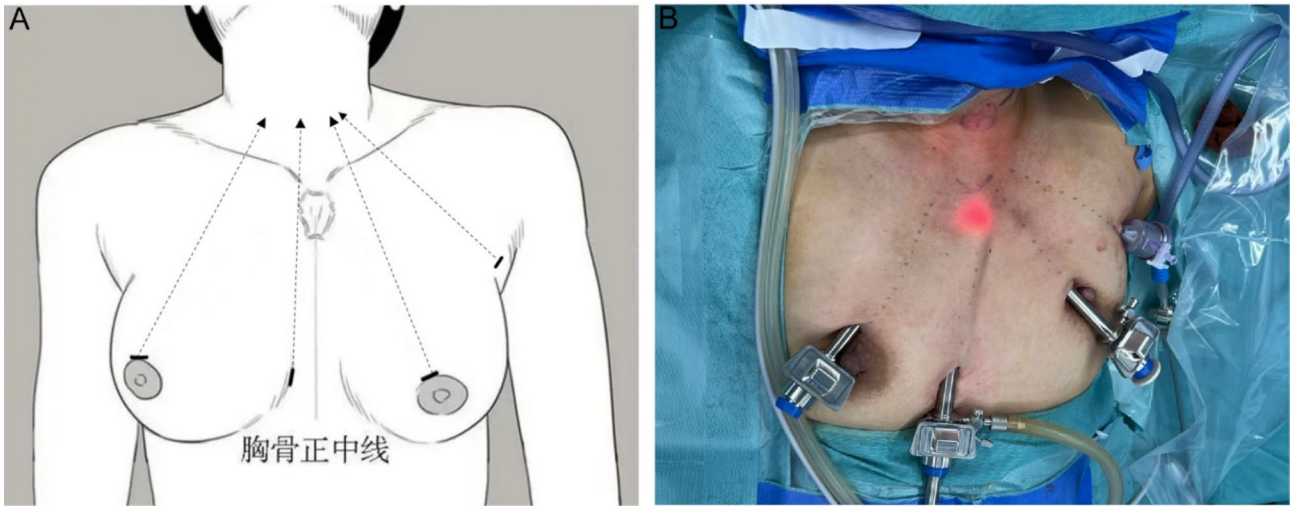

Fig. 1 (**A**) Incision location for robot-assisted thyroidectomy; (**B**) Intraoperative picture

Fig. 2 A. Remote docking for robotic surgery

the ultrasonic scalpel. During the procedure, careful anatomical dissection preserved the right superior laryngeal nerve, recurrent laryngeal nerve, and parathyroid glands, retaining one superior and one inferior parathyroid gland in situ. Under specimen bag protection, the excised thyroid tissue was retrieved through the 12 mm incision, with no parathyroid tissue observed upon inspection. Intraoperative frozen pathology indicated the presence of papillary thyroid carcinoma in the left thyroid lobe. A 12 Fr negative pressure drainage tube was placed in the left thyroid bed and exited through the right chest wall incision, which was then secured. The incisions were closed (Fig. 2).

Result

Histopathological examination confirmed the diagnosis of papillary thyroid carcinoma, classified as pT1N0M0 according to the TNM staging system. The remote surgical procedure was successfully executed utilizing a standard 5G network infrastructure, maintaining uninterrupted connectivity throughout the operation without any instances of signal degradation, transmission delays,

or technical latency. The entire surgical intervention proceeded uneventfully, with no occurrence of network interruptions or cybersecurity breaches. The total operative time was recorded at 170 min, accompanied by minimal intraoperative blood loss (5 mL). Postoperatively, the patient exhibited no signs of cervical hematoma, hoarseness, or hypocalcemia. Postoperative recovery was good.

Discussion

Since Huscher first performed endoscopic thyroidectomy in 1997 [12], the exploration of minimally invasive techniques for thyroid surgery has never ceased. Just two years later, Miccoli performed the first minimally invasive video assisted thyroidectomy (MIVAT) [13]. Over the subsequent decades, the increasing emphasis on aesthetic outcomes and patient satisfaction has driven substantial innovation in surgical approaches. This paradigm shift has led to the development and refinement of various endoscopic remote-access techniques, each offering distinct anatomical pathways and technical advantages. Among these, the most representative and clinically utilized methods include the gasless transaxillary endoscopic thyroidectomy (GTET), bilateral axillo-breast approach (BABA), retro-auricular (RA) approach, and transoral endoscopic thyroidectomy via vestibular approach (TOETVA) [14].

Simultaneously, great strides have been made in the development of surgical assist robots, which have emerged to overcome the limitations of traditional laparoscopic surgery. Robotics offers a higher level of endoscopic surgery, not only by having a higher definition 3D view, but also by having a higher degree of instrumentation freedom, which eliminates hand tremor while adding additional wrist motion. In 2007, Chung et al. first employed the da Vinci robotic platform for robot-assisted transaxillary thyroidectomy (RATS) [15]. Subsequently, robotic systems developed methods for bilateral axillary-breast and RA approaches. Compared to RA, the BABA route offers a larger operating space, and the introduction of the axillary access port significantly conserves physical effort and labor, gradually gaining clinical recognition and usage [16].

The evolution of telemedicine has been profoundly shaped by technological advancements over the past two centuries. The earliest documented instance of remote healthcare communication dates back to the 1860s, when telegraph systems were employed to relay critical medical information about wounded soldiers to distant medical teams [17]. This was followed in 1950 by heartbeat transmissions between New York and Europe (Paris and Rome), the first transatlantic telemedicine data transfer [18]. A major breakthrough occurred in 1974 when Bird et al. implemented a real-time telemedicine system, facilitating the remote examination of 1,000 patients between Massachusetts General Hospital's emergency department and Boston Airport through dedicated television and audiovisual connections [17]. Since then, surgeons have continually explored remote surgery, culminating in the first transatlantic remote cholecystectomy performed by Jacques Marescaux in 2001 on a patient in Strasbourg, France [19]. This renowned "Lindbergh operation" utilized the Zeus robotic system, completing the procedure via a dedicated fiber-optic connection at 10 megabits per second, with a total duration of 54 min.

Despite the remarkable progress in telesurgical technology, its implementation has been significantly constrained by the limitations of network transmission systems. Traditional methods of long-distance data transfer have been plagued by compromised signal quality and excessive latency, which pose substantial risks to patient safety, particularly during critical intraoperative decision-making processes [20]. In the field of network communication, the 5G is the latest generation of cellular mobile communication technology. It is also an extension of 4G (LTE- a or WiMax), 3G (UMTS or LTE), and 2G (GSM) technologies, enabling more stable data transmission, with speeds 100 times faster than its predecessors (10 GB/s) and reducing latency to 1–2 milliseconds, eliminating delays perceptible to the human brain while increasing the number of simultaneous device connections by 100 times [21]. The combination of new robotic systems with 5G technology has made remote surgical procedures a reality [22, 23]. Telesurgery saves and optimizes healthcare resources, maximizing the availability of quality surgical care in disaster areas, battlefields and areas where medical talent is lagging behind.

While 5G tele-robotic-assisted surgery represents a significant technological advancement, it is not without limitations. The current implementation faces several challenges, including substantial acquisition costs, stringent equipment specifications, and unresolved ethical and technical safety considerations. However, the primary benefit of 5G technology lies in its capability to enable long-distance remote control with minimal structural requirements (such as antennas and routers). Therefore, in underdeveloped regions or areas lacking experienced surgeons, especially those with a high incidence of thyroid cancer, 5G remote surgery may represent an optimal resource. This study presents the world's first 5G remote robotic-assisted transcervical thyroidectomy, providing a reference for the future widespread implementation of 5G remote robotic surgeries.

Abbreviations

5G fifth	Generation wireless systems
TI RADS	Thyroid imaging reporting and data system
MIVAT	Minimally invasive video assisted thyroidectomy
GTET	Gasless transaxillary endoscopic thyroidectomy
BABA	Bilateral axillo breast approach
RA	Retro auricular

TOETVA Transoral endoscopic thyroidectomy via vestibular approach
RATS Robot assisted transaxillary thyroidectomy

Author contributions
SJY and YW designed the study, analyzed the data. SJW and NW wrote the manuscript, collected and analyzed the research data. YQW and RJ contributed to the samples and clinical data collection. SJY and YW supervised the study and revised the manuscript. All authors have read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participants
This study was approved by the Ethics Committee of South China Hospital, Medical School, Shenzhen University, approval number: HNLS20220714001-A.

Consent for publication
Written, informed consent for publication was obtained from all participants in this study.

Competing interests
The authors declare no competing interests.

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