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OVERVIEW OF MEDICAL IMAGING TECHNOLOGY

Before the advent of modern medical imaging technologies, physicians mainly relied on physical examination and limited laboratory tests for diagnosis, resulting in only indirect and constrained understanding of internal anatomical structures. As clinical demand for early screening, accurate diagnosis, and perioperative assessment has increased, the ability to visualize internal organs without surgical incision has become a key clinical pain point.

Against this backdrop, various medical imaging technologies have been developed, among which CT, MRI, and ultrasound are the three most widely used modalities in clinical practice. CT utilizes X-rays and tomographic reconstruction to rapidly generate high-resolution cross-sectional images of multiple body regions; MRI employs strong magnetic fields and radiofrequency pulses to provide superior soft-tissue contrast; ultrasound relies on acoustic reflections to produce real-time images, involves no ionizing radiation and is relatively portable. These three modalities differ in imaging principles and imaging characteristics, and are largely complementary in clinical practice.

	CT	MRI	Ultrasound
Description	• Obtain cross-sectional or 3D images of the human body using X-ray computed tomography	• Use magnetic fields and radio waves to excite hydrogen atoms and image via their resonance signals	• Use differences in ultrasound echoes reflected by various tissues to generate images
Advantages	• Fast scanning speed • Excellent imaging of bones and lungs	• Radiation-free • High soft tissue resolution	• Relatively low cost • short examination time
Disadvantages	• Involves radiation • Lower soft tissue resolution compared to MRI	• Longer scanning time • Limitations for patients with metal implants	• Significantly affected by gas & bone • Poor imaging of deep tissues • Relatively low resolution

Source: CIC

CT is currently the most widely deployed and commonly used medical imaging modality in routine clinical practice, primarily due to its fast-scanning speed and stable, reproducible image quality. MRI is characterized by high soft-tissue contrast, multi-planar imaging capability, and the absence of ionizing radiation, and in certain settings can provide both anatomical and functional information. However, in specific applications such as lung imaging, MRI is subject to inherent technical limitations: the low proton density and short relaxation times of pulmonary parenchyma, together with air-tissue susceptibility effects, may result in low signal intensity and variable image quality. Ultrasound offers real-time imaging and relatively low examination costs, but is highly operator-dependent, with considerable variability in image acquisition and interpretation across different physicians.

Against this backdrop, the deep integration of AI with medical imaging technologies to further amplify the strengths of each modality has become a significant trend in the development of the medical imaging device industry. AI broadly refers to technologies that enable computer systems to simulate certain aspects of human intelligence, such as perception, pattern recognition, learning and decision-making, by automatically discovering patterns and decision rules from data. As AI technologies continue to mature and be refined, they are increasingly being applied to medical imaging devices and associated software, thereby driving the development of more advanced and intelligent medical imaging systems.

As AI technologies are progressively embedded into the hardware and software of imaging systems, AI-enabled medical imaging devices have emerged, whereby image reconstruction, noise reduction, lesion detection and workflow management are increasingly supported by algorithm-driven automation. Among the major imaging modalities, CT which given the large installed base and high examination volumes, is generally regarded as the modality with the greatest modalities best suited for AI integration. These characteristics provide substantial and relatively consistent data inputs for model training, enabling AI algorithms to enhance image quality in low-dose and fast-scan reconstruction, mitigate motion and metal artefacts, and assist in certain lesion detection, measurement and triage tasks, thereby helping to improve imaging quality and diagnostic efficiency. In the future, as AI-enabled solutions on CT platforms are further validated and scaled in clinical practice, their technical pathways and clinical experience are expected to be progressively extended to MRI, ultrasound and other medical imaging devices, thereby facilitating deeper integration of AI across the medical imaging equipment sector.

OVERVIEW OF SURGICAL ROBOTS

A surgical robot is a multidisciplinary medical device that integrates mechanical engineering, biomechanics, and computer science. It is designed to assist surgeons in performing minimally invasive procedures with enhanced precision, stability, and control. By converting surgeons' hand movements into precise, scaled, and tremor-free actions, surgical robots improve the accuracy and safety of complex procedures, reduce surgical trauma, and support faster patient recovery.

Surgical robots are typically configured as integrated systems comprising a surgeon console or operator workstation, one or more patient-side robotic arms, imaging and navigation modules and system control software, with the patient-side robotic arms serving as the core hardware module that directly performs surgical tasks. Currently, leveraging decades of development in multi-joint robotic arm design and high-precision motion control in the industrial robotics field, these technologies have been rapidly extended and adapted for use in surgical applications. A multi-joint robotic arm consists of several connected segments and joints that enable flexible, precise and repeatable movements, and the proven accuracy and reliability of such industrial platforms allow them to be adapted relatively quickly for medical use once they are redesigned to meet clinical safety and sterility requirements. This robotics arm technology combined with increasingly mature algorithms and medical imaging technologies, assist surgical robots to enhance the precision and stability of surgical procedures and contribute to the ongoing transition of surgery toward more minimally invasive, standardized and digitalized practice.

Evolution Phase		Description
Late-20th century	Targeted Examination	• Early surgical robots were mainly used for targeted positioning based on pre-operative static imaging, with limited real-time adjustment and relatively narrow procedure coverage
Early-21st century	Endoscopy	• Endoscopic platforms enabling minimally invasive procedures in urology, general surgery and gynecology, and forming the foundation of modern robotic systems
	Surgical Robots	• Surgical robots are enhancing procedures through pre-operative planning, intra-operative navigation and semi-active execution; similar concepts, they are also applied in early percutaneous puncture surgical robots
2020-Future	Automation and intelligence	• Next-generation platforms integrating AI-assisted planning, real-time sensing, connectivity and higher degrees of automation

Source: CIC

Since the late 20th century, surgical robots have evolved into increasingly sophisticated platforms. Looking ahead, the deep integration of AIdriven medical image processing with surgical robotic systems is expected to unlock functions such as automated image registration and fusion, lesion and anatomy recognition, real-time instrument tracking, intraoperative decision support and workflow optimization. AI algorithms can help extract more precise, standardized information from CT, MRI and endoscopic images, and feed this information back to the robotic system to improve planning and execution of complex maneuvers. Some leading manufacturers, such as Da Vinci, have already begun to introduce AI-enabled features, gradually incorporating algorithm-based assistance into vision, instrumentation and procedural guidance. As AI continues to empower surgical robots, their existing advantages in precision, stability and minimally invasive operation are expected to be further amplified, supporting more standardized, data-driven and scalable delivery of complex surgical procedures.

Advantages of Surgical Robots

- ***Enhancing Surgical Precision for Surgeons***

Surgical robots enhance procedural accuracy by combining preoperative imaging, patient-specific planning and controlled execution, whether through surgeon-controlled manipulators or semi-/fully automated guidance. These systems help maintain planned trajectories, optimize instrument positioning, and reduce manual variability across operators, supporting more consistent and reproducible technical performance in complex procedures.

- ***Clinical Benefits for Patients Through Reduced Trauma and Improved Recovery***

Robotic surgery can lessen operative trauma and support faster postoperative recovery compared with conventional open procedures. A systematic review of 14,448 patients found that robotic surgery was associated with approximately 50% lower blood loss and nearly 70% shorter hospital stays than open surgery, indicating meaningful benefits in perioperative safety, rehabilitation time and overall patient experience.

- ***Promotion of Standardization and Scalable Delivery of High-Quality Surgical Services***

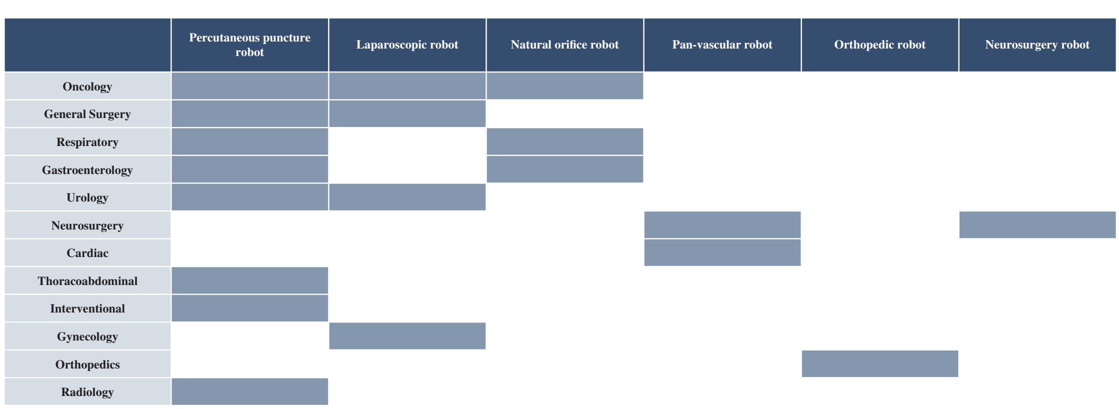
Surgical robots enable a higher degree of procedural standardization by minimizing performance variations between individual surgeons. Built-in digital control systems and automated motion protocols ensure consistent operation across different hospitals and regions. The ability to record, analyze, and reproduce surgical data supports evidence-based quality management and accelerates the training of new surgeons, laying the foundation for large-scale, standardized clinical application.

- ***Health-Economic Benefits and Contribution to Reducing Social Healthcare Burden***

From a health-economic perspective, robotic-assisted surgery may reduce long-term medical expenditures by lowering complication rates, shortening inpatient length of stay, and decreasing the need for revision procedures. Improved accuracy and minimally invasive techniques lessen postoperative morbidity and support faster patient recovery, which can reduce resource utilization and improve hospital operational efficiency. Over time, these efficiencies help mitigate broader societal healthcare burdens, including costs associated with prolonged hospitalization, postoperative management, and productivity loss, contributing to a more sustainable healthcare delivery framework.

Applications of Surgical Robots

Surgical robots are applied across multiple clinical disciplines, including general surgery, oncology, orthopedics, neurosurgery, and interventional procedures. Different types of robots serve distinct functions, such as percutaneous puncture in tumor diagnosis, laparoscopic systems in general and gynecologic surgery, and orthopedic and neurosurgical robots. Among these, percutaneous puncture robots have the broadest departmental coverage, with applications spanning oncology, general surgery, respiratory, gastroenterology, urology, thoracoabdominal, interventional, and imaging-guided procedures. Their multi-department applicability contrasts with other robot categories that are typically concentrated in single surgical specialties, underscoring the versatility and cross-disciplinary potential of puncture-based robotic systems.



Source: Expert Interview, CIC

Industry Chain of Surgical Robot Market

- ***Upstream of Surgical Robot Market***

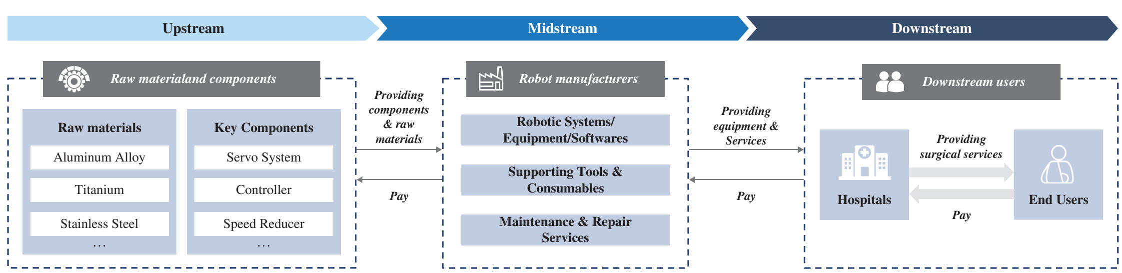
The upstream segment includes suppliers of core components and technologies such as precision actuators, sensors, imaging systems, and medical-grade materials. These elements determine the accuracy, stability, and overall performance of surgical robots.

- ***Midstream of Surgical Robot Market***

The midstream segment acts as the system integrator, responsible for overall robot architecture and key modules such as imaging, navigation, and motion-control systems. By aligning upstream technologies with regulatory and clinical requirements, it serves as the pivotal link that turns innovation into clinically deployable surgical robots.

- ***Downstream of Surgical Robot Market***

The downstream segment comprises hospitals and medical institutions that adopt and operate surgical robots. Market growth is driven by the rising demand for precision surgery, improved efficiency, and wider clinical adoption.



Source: CIC

Comparison of Development Status between the Surgical Robot Market in China and Other Mature Market

Globally, the surgical robot market has become gradually mature in certain clinical fields, but overall penetration across the broader surgical landscape is still expanding. The United States and major European countries represent relatively mature markets with well-established regulatory and clinical systems, these regions lead in terms of technological innovation, product diversity, and clinical validation, simultaneously, Japan and South Korea have achieved a moderate level of market development, supported by structured regulatory frameworks and government-backed initiatives for clinical application. Penetration remains concentrated in large medical centers, and further growth is expected as reimbursement mechanisms and surgeon training systems continue to improve.

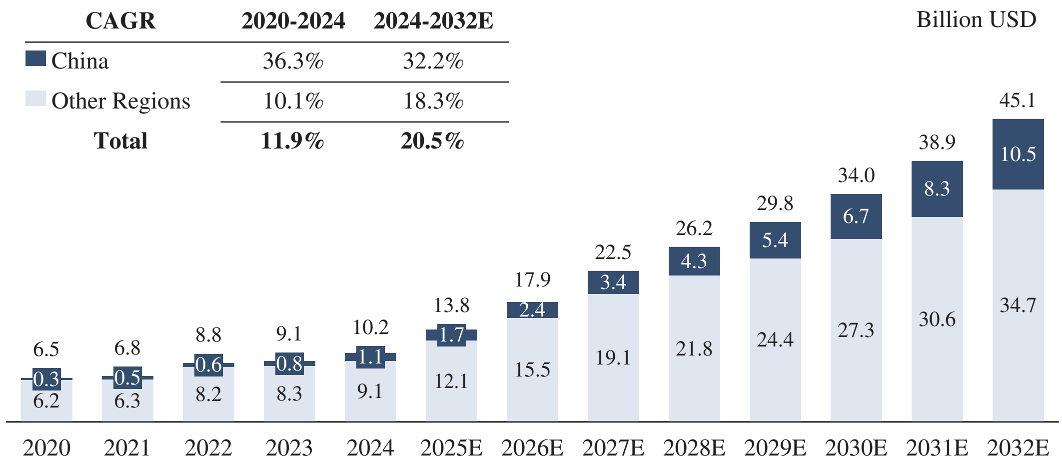
In contrast, China's surgical robot market has entered a phase of accelerated commercialization since 2020. Supported by favorable policies, streamlined regulatory pathways, and continuous domestic innovation, the market has expanded across multiple surgical disciplines, including laparoscopic, orthopedic, percutaneous puncture, and other applications. Although the current penetration rate remains lower than that of developed markets, rising hospital demand, advancing localization of core technologies, and declining equipment costs are expected to support significant market growth over the next decade. In the orthopedic segment, for instance, the penetration rate of robot-assisted spinal surgeries in China was approximately 1.2% in 2024 and is projected to reach 10.7% by 2032, compared with 9.4% in the United States in 2024. By contrast, markets in Southeast Asia and the Middle East remain at nascent stages, with applications largely concentrated in major hospitals and constrained by reimbursement coverage and the availability of surgeon training resources.

Global Surgical Robot Market Size

The development of the global surgical robot market is driven by a combination of technological innovation, increasing clinical demand, and structural changes within healthcare systems. Continuous advancements in imaging, navigation, and robotic control technologies have enhanced surgical precision and broadened the scope of minimally invasive procedures. At the same time, hospitals worldwide are accelerating the adoption of intelligent surgical systems to improve operating efficiency and reduce human error.

The global surgical robot market was valued at approximately US$10.2 billion in 2024 and is projected to reach US$45.1 billion by 2032, representing a CAGR of 20.5%. Growth is primarily driven by the increasing adoption of minimally invasive surgical procedures, continuous technological advancements in imaging, navigation, and automation, as well as supportive regulatory and reimbursement environments. In particular, China is expected to contribute significantly to global expansion, with its market size rising from US$1.1 billion in 2024 to US$10.5 billion by 2032, supported by policy incentives, local manufacturing capabilities, and cost advantages. The overall market outlook reflects accelerating hospital adoption, broader clinical indications, and the growing trend toward intelligent, data-driven surgical systems.

Global Surgical Robot Market Size, 2020-2032E



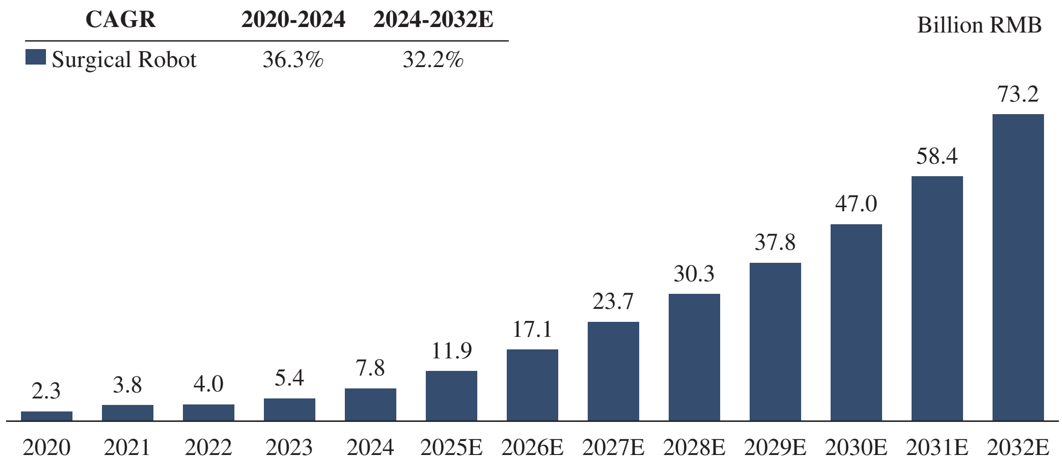
Source: CRSA, OECD, FDA, NMPA, Expert Interview, Annual Report, CIC

China's Surgical Robot Market Size

The rapid expansion of China's surgical robot market is driven by continued policy support for high-end medical equipment, accelerated regulatory approvals for domestically developed systems, and increasing investment in hospital digitalization, which are creating a favorable environment for adoption. The rising demand for minimally invasive and precision surgeries, combined with technological improvements in imaging guidance and control algorithms, is expanding the range of applicable surgical indications. Furthermore, cost reductions through local manufacturing and the improvement of surgeon training systems are enhancing affordability and accelerating clinical acceptance across medical institutions.

The surgical robot market in China reached approximately RMB7.8 billion in 2024 and is projected to grow to RMB73.2 billion by 2032, representing a CAGR of 32.2%. The market primarily comprises laparoscopic robots, orthopedic robots, neurosurgery robots, percutaneous puncture robots, as well as other emerging categories. In particular, China's orthopedic and neurosurgery surgical robot markets are expected to reach approximately RMB 19.8 billion and RMB 2.0 billion, respectively, by 2032, representing a CAGR of 50.9% and 22.6% from 2024 to 2032. Overall, China's market is transitioning from single-application adoption toward diversified, data-driven, and precision-focused robotic surgical ecosystems.

China's Surgical Robot Market Size, 2020-2032E



Source: CRSA, OECD, NMPA, Expert Interview, Annual Report, CIC

Growth Drivers & Future Trends of Surgical Robot Market

- ***Rising Patient and Hospital Demand***

With improving public health awareness and a growing preference for minimally invasive treatment, patients are increasingly seeking surgical options that offer better perioperative experience and long-term functional outcomes. As overall surgical volume and complexity continue to increase across multiple specialties, surgical robots provide a pathway to deliver complex procedures in a more controlled and reproducible manner, aligning well with patients' demand for higher-quality, technology-enabled care.

- ***Payment Reform, Reimbursement Expansion and Policy Support***

From a policy and payment perspective, China is gradually building a more supportive environment for surgical robots. Although robot-assisted surgery has not yet been fully incorporated into the national basic medical insurance system, several provinces have launched pilot reimbursement programs and clarified charging standards. For instance, in 2023, Jiangxi Province included orthopedic robot–related surgical consumables in the "Jiangxi Medical Consumables Reimbursement Catalogue (2023)", marking a significant step toward cost inclusion at the provincial level. At the national level, initiatives such as the "Robotics+" Application Action Implementation Plan and the Action Plan to Promote Large-scale Equipment Renewals and Trade-ins of Consumer Goods explicitly encourage hospitals to adopt robotic systems for precise and minimally invasive procedures, together helping to improve affordability, expand access, and support wider clinical adoption of surgical robots. Globally, regulators in other markets are likewise refining coding and reimbursement frameworks for robot-assisted procedures, underpinning the long-term growth prospects of the surgical robotics industry.

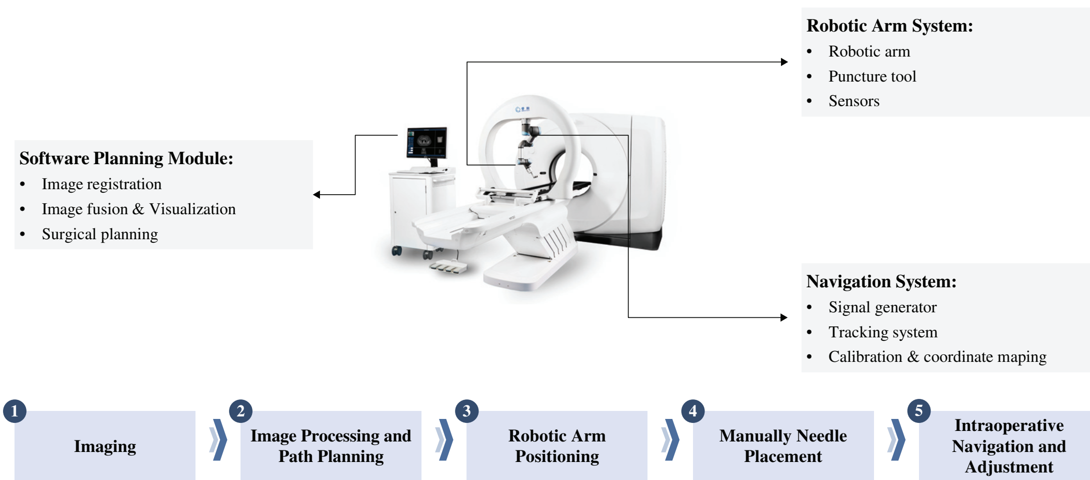
- ***Technological Advancement and Artificial Intelligence Integration***

The integration of AI has become a core driver of system innovation, supporting functions such as intelligent medical image interpretation, automated surgical path planning, and real-time navigation assistance. These technologies not only improve surgical accuracy and operational safety but also lay the foundation for remote surgery and tele-collaboration, expanding access to high-quality surgical care in regions with limited medical resources.

OVERVIEW OF PERCUTANEOUS PUNCTURE SURGICAL ROBOTS

Puncture-based surgical procedures constitute a fundamental and indispensable clinical approach in the diagnosis of multiple diseases. As the prevalence of malignant tumors and other solid organ lesions continues to rise, percutaneous puncture has become one of the most essential and frequently performed minimally invasive interventions in clinical practice. However, the overall technical capability and procedural standardization of puncture surgery remain uneven, particularly in primary and secondary hospitals, where limited operator experience continues to constrain the precision, safety, and accessibility of such procedures.

A percutaneous puncture surgical robot is an advanced precision system that assists physicians in performing minimally invasive puncture procedures with enhanced accuracy, safety, and reproducibility. By integrating preoperative imaging, the system identifies anatomical targets, formulates an optimal puncture path, and positions the robotic arm accordingly. In typical use, the robot aligns and stabilizes the needle guide or biopsy channel, while the physician manually inserts and advances the puncture needle along the planned trajectory. Throughout the procedure, sensors and real-time imaging provide continuous navigation and feedback, helping to correct deviations, reduce manual error, and minimize tissue trauma. Structurally, a percutaneous puncture surgical robot generally comprises a navigation system, a software planning module, and a robotic arm, which together enable real-time tracking, adaptive positioning, and intelligent feedback to improve the precision and efficiency of interventions.



Source: CIC

Over the past decades, percutaneous puncture techniques have evolved from fully manual, experience-based procedures to percutaneous puncture navigation systems and, more recently, to percutaneous puncture surgical robots, progressively incorporating imaging guidance and computer assistance. Building on this technological trajectory and leveraging advances in AI algorithms, percutaneous puncture surgical robots now represent an integrated application of AI, medical imaging and robotics, combining intelligent planning and analysis, image-guided navigation and precise mechanical execution. This integrated approach further enhances the accuracy, consistency and minimally invasive nature of puncture procedures and supports their application across a broader range of clinical scenarios.

Comparison between Percutaneous Puncture Surgical Robots and Traditional Percutaneous Puncture Surgery

Compared with traditional percutaneous puncture surgery, percutaneous puncture surgical robots offer notable advantages in precision, efficiency, and safety. Traditional procedures rely heavily on the surgeon's manual skill and experience, which may result in variability due to human fatigue or hand instability. In contrast, robotic systems combine planning, navigation, and real-time control to enhance positioning accuracy and procedural consistency.

Robotic assistance also shortens surgical duration by reducing repeated manual adjustments and enabling more streamlined operations. By reducing the need for repeated needle repositioning and verification, robotic workflows can decrease the number of intraoperative CT scans and thereby lower radiation exposure for both patients and clinical staff. In addition, standardized robotic workflows lower the learning threshold for surgeons, improving training efficiency and supporting wider clinical adoption. The enhanced precision of robotic systems minimizes tissue trauma and postoperative complications, contributing to faster patient recovery and more stable clinical outcomes.

	Percutaneous puncture surgical robot	Traditional percutaneous puncture surgery
Accuracy and Stability	• Positioning and orientation accuracies of 3-5 mm	• Positioning and orientation accuracies of ~ 7 mm
Surgical Duration	• 10-25 mins procedure time and 1 needle insertion	• 25-40 mins procedure time and may require multiple punctures
Learning Curve	• **Lower technical difficulty** and dependence on operator experience, and shortening the learning curve	• **High entry barrier**, relying on highly experienced physicians
Postoperative Complications	• **<5% severe complications rate** • Higher puncture success with fewer needle passes, resulting in fewer postoperative complications and faster recovery.	• **~10% severe complications rate** • Repeated needle insertions increase tissue trauma and raise the risk of complications such as bleeding and pneumothorax

Source: Literature review, CIC

Beyond the operating room, robotic systems also address broader healthcare challenges. In regions where experienced surgeons are scarce, such as third-tier cities and primary hospitals, robot-assisted platforms can help bridge the expertise gap by standardizing procedures and reducing reliance on individual skill. This aligns with government-led centralized procurement strategies, as robotic technology not only improves patient outcomes but also supports more consistent provision of high-quality surgical care across different healthcare settings. By facilitating earlier detection and minimally invasive treatment of tumors, robot-assisted systems may enable more patients to receive definitive care at qualified hospitals, thereby supporting incremental procedure volumes and revenue opportunities for healthcare institutions. From a health economics perspective, earlier diagnosis and intervention for oncological diseases can help avoid downstream costs associated with late-stage cancer management and reduce the overall burden on the healthcare system and society.

Comparison between Percutaneous Puncture Surgical Robots and Percutaneous Puncture Navigation System

- ***Percutaneous Puncture Navigation Systems***

Percutaneous puncture navigation systems primarily function as auxiliary positioning and planning tools during interventional procedures. They rely on preoperative imaging and real-time tracking to assist physicians in locating targets and determining optimal puncture paths. However, as these systems do not incorporate multi-degree-of-freedom robotic arms, they cannot autonomously execute the planned trajectory. The final outcome remains influenced by the operator's hand movements and technique, which may introduce variability and limit the consistency of puncture accuracy and procedural stability.

- ***Percutaneous Puncture Surgical Robots***

Percutaneous puncture surgical robots integrate planning, navigation, and execution into a unified platform. Equipped with multi-degree-of-freedom robotic arms, these systems enable physicians to perform puncture operations through robotic-assisted positioning and automated alignment of the planned puncture trajectory. In typical workflows, the robotic arm moves to the pre-planned position and orients the puncture channel, while the physician advances the needle manually along this trajectory. The system is capable of dynamically monitoring patient movement and soft tissue deformation, helping to maintain high stability and consistent precision throughout the procedure. By standardizing trajectory planning and channel positioning and reducing dependence on free-hand execution, robotic systems effectively minimize human error, enhance repeatability, and improve both accuracy and safety.

Classification of Planning and Navigation Technologies

Imaging and navigation technologies constitute the technological foundation of percutaneous puncture robotic systems. Preoperative imaging planning technologies primarily include CT, MRI, and ultrasound, which are used to design puncture trajectories and localize targets. Navigation and positioning technologies, such as image-guided navigation, optical tracking navigation, and electromagnetic navigation, provide real-time intraoperative guidance and help the robotic arm and needle follow the planned path.

Classification of Planning and Navigation Technologies

	Classification	Description	Advantages	Disadvantages
Preoperative Imaging Planning	CT	• Obtain cross-sectional or 3D images of the human body using X-ray computed tomography	• Fast scanning speed • Excellent imaging of bones and lungs	• Involves radiation • Lower soft tissue resolution compared to MRI
	MRI	• Use magnetic fields and radio waves to excite hydrogen atoms and image via their resonance signals	• Radiation-free • High soft tissue resolution	• Longer scanning time • Limitations for patients with metal implants
	Ultrasound	• Use differences in ultrasound echoes reflected by various tissues to generate images	• Relatively low cost • short examination time	• Significantly affected by gas & bone • Poor imaging of deep tissues • Relatively low resolution
Navigation and positioning	Image-Guided Navigation	• Uses CT imaging to plan and track needle trajectories with integrated image reconstruction and automatic localization	• Rapid turnover rate • No need for marker coordinates on human surface • Compatible with standard CT scanners • Low material cost • Short learning curve	• Requires CT environment
	Optical Navigation	• Cameras are used to spatially locate markers or objects by capturing optical signals	• High data transmission speed • Unaffected by magnetic fields or environmental interference	• High requirements of marker registration • Navigation and positioning fail when the optical path is blocked
	Electromagnetic Navigation	• Sensor coils are attached to the tracked instrument, as the coils move relative to the magnetic fieldgenerator, varying currents are induced, which are used to determine the instrument's position	• By embedding a sensor coil at the tip of the puncture needle, the needle tip can be accurately located inside the body	• Limited working range • Susceptible to magnetic field interference

Source: CIC

From a navigation and positioning perspective, Image-guided navigation uses intraoperative image coordinate with image reconstruction to plan and track needle trajectories, providing high positioning accuracy, and eliminating the need for the implantation of reference coordinate markers on the patient's body surface. Optical navigation employs cameras to track markers on the patient and instruments, enabling fast, high-precision localization, but failing when the optical path is blocked. Electromagnetic navigation places a field generator near the operative field and embeds small sensor coils in the puncture needle, allowing accurate localization of the needle tip inside the body, while its effective range is limited, and it is susceptible to magnetic interference.

Overview of Image-guided Percutaneous Puncture Surgical Robots

Image-guided percutaneous puncture surgical robots represent the advanced generation of image-based interventional systems. Unlike conventional optical or electromagnetic navigation platforms, Image-guided systems leverage imaging derived data coordinates and real-time sensing to visualize internal anatomical structures during the entire surgical process. The robotic system automatically registers and synchronizes CT images with the patient's body position, enabling precise localization of target lesions and direct trajectory planning. This globally original innovation achieves seamless fusion of imaging, moving, and sensing. By integrating imaging and perception into a unified control loop, the system transforms traditional "image-assist" operations into truly image-driven, autonomous navigation.

Advantages of Image-Guided Percutaneous Puncture Surgical Robots

- ***Reduced Preparation Time and Higher CT Suite Turnover***

Compared with optical or electromagnetic navigation systems, which typically require additional reference sensors and image-field coordinate registration before each procedure, image-guided percutaneous puncture robots operate directly within the CT image coordinate system with integrated sensing. By avoiding time-consuming steps such as placing and fine-tuning external reference markers and repeatedly verifying registration, the system is designed to materially shorten pre-operative preparation and puncture time, thereby improving workflow efficiency and enabling a higher number of procedures per CT suite.

- ***Simplified System Design and Workflow for Better Overall Economics***

Conventional navigation platforms, such as optical systems using dedicated tracking cameras and reflective markers or electromagnetic systems with separate field generators and controllers, typically require a standalone navigation console and additional patient-mounted positioning devices alongside the CT scanner. This multi-component architecture increases capital expenditure, maintenance workloads and room-layout complexity for hospitals, while also adding per-procedure consumable costs for patients and prolonging intraoperative set-up. In contrast, image-guided percutaneous puncture robots adopt a more streamlined system design by integrating the robotic arm and sensing-navigation functions directly with the CT system and operating within the CT image coordinate framework, without the need for an external navigation host or body-surface positioning rings. The simplified hardware configuration and reduced reliance on disposable positioning devices lower both equipment investment and ongoing consumable usage, enhancing overall cost-effectiveness for hospitals across different tiers and making the system easier to deploy, maintain and operate in routine clinical practice.

- ***Short Learning Curve and Wider Adoption Among Primary-Care Institutions***

Other navigation technologies often require physicians to undergo prolonged training in coordinate modeling workflows and surface marker placement. Image-guided percutaneous puncture robots build on conventional CT-guided workflows and automate key steps such as image-coordinate mapping and path execution, without relying on complex patient-specific modeling. As a result, the learning curve of image-guided navigation robot-assisted procedures is relatively short, facilitating faster skill transfer to junior doctors and teams in primary and regional hospitals and helping to standardize puncture quality across a broader hospital base.

Applications of Percutaneous Puncture Surgical Robots

Percutaneous puncture surgical robots have shown broad clinical applicability in interventional diagnosis, particularly for pulmonary nodules, abdominal tumors, and prostate cancer. Under CT or MRI imaging, the system assists physicians in formulating precise puncture paths and executing targeted operations with high spatial accuracy. By monitoring for respiratory motion and anatomical complexity, robotic assistance reduces repeated needle adjustments, minimizes tissue trauma, and lowers the risk of complications such as bleeding and pneumothorax. In pulmonary and abdominal interventions, these systems enhance lesion targeting and procedural efficiency, while in prostate biopsy, they improve puncture uniformity and diagnostic accuracy.

The increasing adoption of percutaneous puncture surgical robots reflects a broader transformation of interventional medicine toward more imaging-guided, precision-based, and data-driven practice. As indications expand from lung and liver lesions to the thyroid nodules, breast nodules, spinal puncture and other soft-tissue masses, these systems are being applied across a wider range of minimally invasive procedures. Through the integration of real-time navigation, intelligent trajectory control and quantitative imaging feedback, such systems are reshaping standards of minimally invasive surgery and accelerating the transition toward intelligent and automated interventional care. These trends are particularly evident in key indications such as pulmonary nodules, abdominal tumors and prostate tumors, where rising disease burden and the limitations of conventional puncture techniques are accelerating the adoption of percutaneous puncture surgical robots as more precise, image-guided solutions.

Indication		Pain Points	Advantages
Pulmonary nodules		• Movement due to respiratory motion • Multiple CT scans • Frequent needle adjustments • Complication such as pneumothorax and hemoptysis	• Plan the optimal puncture path • Improve puncture success rate • Reduce the risk of complications • Minimize radiation exposure for both doctors and patients
Abdominal tumor	Liver tumors Kidney lesions Pancreatic cysts Other masses	• Technically challenging and carrie a high risk due to the dense distribution of adjacent organs and blood vessels • Steep learning curves • Frequent needle adjustments • Increase radiation exposure	• Accurately locates lesions • Protect important structures such as blood vessels and nerves • Shorten operation time • Reduce bleeding and unnecessary damage
Prostate tumor		• Require the cooperation of two or more doctors • Uneven puncture • Higher rate complications • Certain rate of missed diagnoses	• Reduce puncture complexity • Enhance doctors' puncture accuracy • Increase the positive detection rate in patients • Lower missed and incorrect diagnoses • Alleviate patient suffering

Source: CIC

Pulmonary nodules are one of the primary indications for percutaneous biopsy. With the continued advancement of global lung cancer screening programs, the detection rate of pulmonary nodules has increased significantly, and it is estimated that approximately 73.5 million individuals are identified with pulmonary nodules each year worldwide through imaging examination. In 2024, the global prevalent population with pulmonary nodules was estimated at about 1,569.5 million, and this figure is expected to increase to approximately 1,597.4 million by 2032. In China, the prevalence of pulmonary nodules was estimated at around 303.0 million in 2024 and is projected to reach 337.3 million by 2032, with nationwide screening programs detecting roughly 16.4 million positive pulmonary nodules in 2024 alone.

Abdominal solid tumors, particularly malignancies of the liver, kidney and pancreas, constitute an important group of indications for image-guided percutaneous puncture. In China, the incident cases of liver, kidney, and pancreatic cancers were estimated at approximately 361.9 thousand, 73.1 thousand, and 125.0 thousand, respectively, in 2024, illustrating the substantial and growing burden of abdominal and related solid tumors in the population. As cross-sectional imaging becomes more widely used for screening, diagnosis and follow-up, the number of patients requiring image-guided percutaneous biopsy or ablation for abdominal lesions is expected to continue to increase. However, despite this growing disease burden and wider use of imaging, overall diagnostic rates for abdominal indications remain low. Taking liver cancer as an example, it was estimated that in 2019 only about 0.09% of the Chinese population aged 35–74 years underwent liver cancer screening. In addition, published studies indicate that only around 10%–20% of high-risk patients with kidney cancer are aware of or carry a clinical diagnosis. Consequently, the diagnostic rate remains low in abdominal solid tumors.

Prostate tumors represent a major indication for percutaneous biopsy in male patients, particularly in the context of population aging and wider use of prostate-specific antigen testing and multiparametric imaging. In China, incident prostate cancer cases were estimated at about 158.6 thousand in 2024, reflecting a meaningful and rising disease burden. As more patients with elevated PSA or suspicious imaging findings are identified at earlier stages, the demand for accurate, minimally invasive percutaneous biopsy of prostate lesions is expected to grow correspondingly.

Customer Landscape and Key Purchasing Criteria

From an application perspective, percutaneous puncture surgical robots are primarily utilized by Grade III A hospitals that undertake complex interventional procedures in oncology, pulmonology, and urology. These hospitals represent the major early adopters of advanced interventional technologies and play a key role in promoting clinical validation and standardization. Regional secondary hospitals constitute the next layer of users, as they seek to enhance their capabilities in minimally invasive treatment and improve the efficiency and quality of clinical services. With the progressive decline in treatment costs and the continuous optimization of standardized operating workflows, primary and community hospitals are gradually emerging as potential users, particularly in regions with a relative shortage of experienced interventional specialists.

Purchasing priorities differ across hospital tiers. Leading tertiary hospitals generally place greater emphasis on system precision, integration with imaging and navigation platforms, and clinical evidence supporting academic and technical leadership. Secondary hospitals focus on operational efficiency, workflow standardization, and ease of use to facilitate broader team adoption. Primary and community hospitals typically prioritize cost-effectiveness, simplified training, and after-sales service support, given their more limited technical and human resources. To cater to these differentiated needs, manufacturers are expected to offer diversified product portfolios and service models with varying levels of configuration and functionality, while aligning with national and regional centralized procurement initiatives.

Constraints of Percutaneous Puncture Surgical Robot Market

Although percutaneous puncture surgical robots are still at an early stage of commercialization, the market is gradually approaching an inflection point as clinical evidence accumulates and pilot sites expand. However, further penetration is constrained by limited market education and clinical awareness, reimbursement pathways, and the need for service infrastructure. Addressing these constraints will be critical for the market to transition from early adoption to broader, routine clinical deployment.

- ***Market Education and Clinical Awareness***

A major barrier in global markets lies in the challenge of market education. Unlike mature surgical robotics segments, percutaneous puncture robots remain relatively new to many physicians and institutions. Establishing clinical awareness, building confidence in safety and efficacy, and promoting workflow adaptation require long-term investment in physician training, academic publications, and multi-center clinical validation. The difficulty of standardizing education and promotion across diverse healthcare systems makes scaling particularly challenging. To address these gaps, leading manufacturers and clinical centers are increasing investment in structured training programs, proctored cases, collaboration with key opinion leaders, and evidence-generation studies, in order to strengthen physician confidence and gradually embed percutaneous puncture robots into routine practice.

- ***Regulatory and Reimbursement Landscape***

Currently, commercialization is further constrained by heterogeneous regulatory and reimbursement environments across countries and regions. Regulatory authorities such as the FDA, EMA, NMPA, and other regulators in emerging markets impose differing requirements on clinical evidence, safety, efficacy, and post-market surveillance, resulting in extended development timelines and higher compliance costs. Currently, reimbursement pathways for robotic-assisted puncture procedures are still evolving, and coverage remains absent or inconsistent in many jurisdictions. These factors may delay hospital adoption until reimbursement visibility becomes clearer.

- ***After-Sales Service and Support Infrastructure***

Beyond technology performance, widespread adoption of the percutaneous puncture surgical robots depend on reliable after-sales service and support infrastructure. Hospitals require timely installation, system integration, user training, preventive maintenance, and rapid technical troubleshooting once robots enter routine use, creating high expectations for uptime and service quality. In response, manufacturers are building regional service hubs, collaborating with local distributors and service providers, and deploying remote monitoring and support tools to improve responsiveness, reduce downtime, and ensure consistent performance across diverse healthcare systems.

Global Clinical Demands and Key Market Drivers

In 2024, approximately 8.0 million percutaneous puncture surgery cases worldwide, with the figure rising to 8.5 million in 2032. Over the longer term, the market is expected to maintain a stable expansion, reaching about penetration rate in developed markets, partially offset by increasing procedural demand in emerging regions.

- ***United States and Europe: Demand for Competitive Differentiation***

In mature markets, demand for percutaneous puncture surgical robots is primarily concentrated in hospitals and specialized centers that already perform a high volume of interventional oncology, pulmonology or urology procedures. For these institutions, robotic systems are adopted to enhance procedural accuracy, standardize complex image-guided punctures, and differentiate their minimally invasive service offerings in competitive healthcare markets. In Europe, early deployments have likewise focused on leading academic hospitals and comprehensive cancer centers that are actively expanding interventional programs.

- ***Emerging Asia-Pacific Markets (excluding China): Bridging Infrastructure Gaps and Improving Access***

In regions such as India, Southeast Asia, and the Middle East, demand is driven by the need to expand modern interventional capacity in under-served populations. Hospitals invest in robotics to enhance treatment precision while compensating for shortages of senior specialists. However, purchasing decisions are strongly influenced by affordability, simplified training, and local service support. Compared with China, these markets are at an earlier stage of adoption, with slower penetration but strong long-term growth potential as healthcare infrastructure advances.

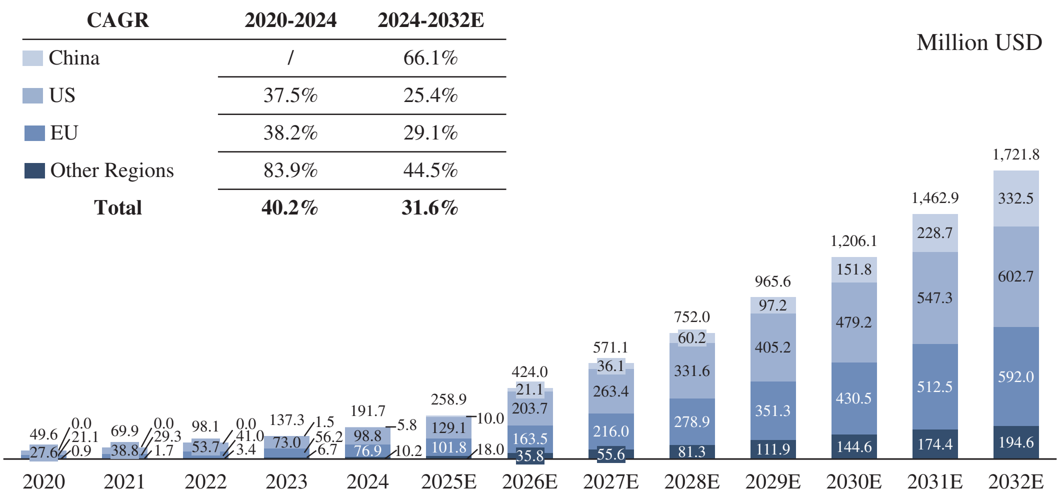
- ***China: Potential under Centralized Procurement and Hierarchical Diffusion***

China's market is characterized by supportive government policies, a large patient population and uneven distribution of interventional expertise. Tertiary hospitals act as early adopters and referral hubs, introducing high-end robotic platforms for complex cases, while regional and secondary hospitals progressively deploy such systems through hierarchical diffusion. Unlike the differentiation-focused private and independent medical centers in mature markets, the current development model in China is shaped by national procurement initiatives, cost control objectives and policy goals to extend high-quality surgical services to provinces and lower-tier cities.

Global Percutaneous Puncture Surgical Robot Market Size

The global percutaneous puncture surgical robot market reached approximately US$191.7 million in 2024 and is projected to grow to around US$1,721.8 million by 2032, representing a CAGR of 31.6% during 2024–2032. Growth is driven by the broader uptake of image-guided interventions across the United States, Europe, and China, where hospitals are increasingly adopting percutaneous puncture surgical robots to enhance procedural accuracy and reduce complication risks. Regionally, the United States and Europe currently dominate the market, benefiting from earlier regulatory approvals and clinical adoption of robotic platforms. In contrast, China has entered a rapid market expansion phase. Leveraging accelerated domestic innovation and hospital digitalization, China is expected to become one of the fastest-growing regions, with a projected CAGR of 66.1% from 2024 to 2032, gradually narrowing the market share gap with the U.S. and Europe.

Global Percutaneous Puncture Surgical Robot Market Size, 2020-2032E



Source: WHO, FDA, NMPA, Expert Interview, Annual Report, CIC

Competitive Landscape of Percutaneous Puncture Surgical Robot Market

The percutaneous puncture surgical robot market has evolved into a competitive landscape characterized by the deep integration of imaging navigation, AI-driven decision-making, and robotic execution. As of the Latest Practicable Date, 7 companies have obtained FDA 510(k) clearance for 15 percutaneous robotic systems. In addition, 4 percutaneous puncture surgical robots are currently in clinical evaluation or premarket submission stages globally, reflecting accelerating innovation and expanding procedural coverage. Meanwhile, leading Chinese manufacturers, which have already obtained regulatory approval in China, are actively expanding into overseas markets.

China's Clinical Demands and Key Market Drivers

The number of percutaneous puncture surgeries for lung and abdominal indications in China reached approximately 3.0 million cases in 2024 and is projected to grow to around 3.5 million cases by 2032, representing a compound annual growth rate of 2.0% during 2024-2032. This steady increase is primarily driven by the rising incidence of lung and liver tumors, greater clinical adoption of image-guided minimally invasive procedures, and improved accessibility of interventional technologies at tertiary and regional hospitals. Moreover, the promotion of early cancer screening and precision diagnosis programs has expanded the demand for biopsy-based procedures, while advancements in percutaneous puncture robotic systems are further improving procedural safety and success rates. The continuous growth of percutaneous puncture procedures indicates a structural shift in China's clinical practice from traditional interventions toward precision, image-guided, and robot-assisted operations, reflecting the advancement of diagnostic technology in modern healthcare.

- ***Expanding Clinical Demand Driven by Oncology Patient Growth***

China continues to report a large and rising number of beginning malignant and solid tumor cases each year. These solid tumors frequently require puncture biopsy during early and mid-stage intervention. Compared with traditional open or manual procedures, percutaneous puncture surgical robots meet the growing clinical need for safer and more precise minimally invasive interventions.

As clinical demand continues to evolve, the treatment cost structure for percutaneous puncture procedures is also undergoing gradual refinement. Current medical pricing policies typically set the base tariff for percutaneous puncture biopsy at approximately RMB 2,000–3,000 per case, while there is still no unified charging standard specifically for percutaneous puncture surgical robots. For systems that only provide navigation and positioning assistance, hospitals usually charge an additional navigation fee equivalent to around 40% of the underlying procedure price, or a fixed surcharge of roughly RMB 1,000–2,000 per case. For robot-assisted procedures, two main pricing approaches have emerged in practice: in regions such as Shanghai and Gansu, robotic procedures are categorized under "AI-assisted treatment technologies," with an additional charge of about RMB 10,000–30,000 per case; in other regions such as Hunan and Hainan, where the robotic system completes or participates in key operative steps to achieve the surgical objective, hospitals may apply a markup of approximately 80%–300% on top of the base procedure tariff.

- ***Policy-Driven Expansion toward Primary and Regional Hospitals***

China's ongoing medical reform and the nationwide implementation of a hierarchical diagnosis and treatment system are promoting the redistribution of medical resources. National policies encourage primary and regional hospitals to improve their diagnostic and treatment capabilities for chronic diseases. In particular, the "15th Five-Year" health service system planning emphasizes strengthening primary-level institutions, establishing county-level medical consortia and improving tiered referral mechanisms, with targets such as managing the vast majority of common conditions within county and township facilities. The increasing availability of advanced interventional equipment, including percutaneous puncture surgical robots, supports the gradual extension of robotic-assisted procedures from tertiary hospitals to lower-tier institutions, accelerating overall market adoption.

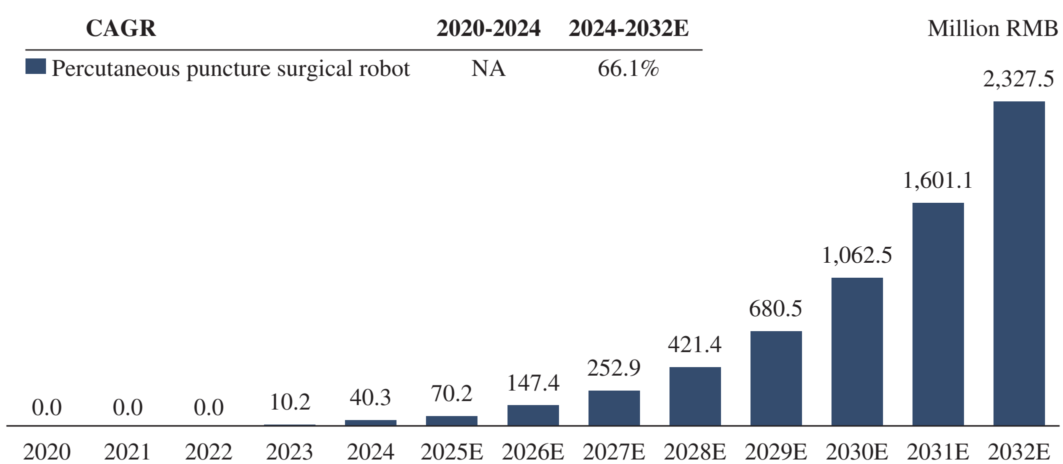
- ***Technological Maturation and Generational Shift in Clinical Adoption***

As percutaneous puncture surgical robot technologies become more mature, the establishment of standardized training systems and operational protocols will drive broader clinical acceptance. Meanwhile, younger digitally proficient physicians show higher acceptance of AI and robotics assisted surgery further shortens the learning curve and accelerating technology diffusion across the healthcare system.

China's Percutaneous Puncture Surgical Robot Market Size

The percutaneous puncture surgical robot market in China is still at an early stage of commercialization, but is expected to grow rapidly over the coming decade. The market size reached approximately RMB40.3 million in 2024 and is projected to surge to RMB2,327.5 million by 2032, representing a CAGR of 66.1% during 2024-2032. This strong momentum is supported by the increasing clinical demand for precise, image-guided minimally invasive interventions and the continuous advancement of robotic systems. The integration of navigation, planning, and automated execution modules enables these systems to significantly enhance targeting accuracy and procedural safety, particularly in complex tumor biopsies and interventional therapies. The rapid market expansion also reflects China's accelerating shift from manual image-guided procedures to fully robotic-assisted interventional platforms, driven by policy incentives, domestic technological innovation, and growing hospital investment in intelligent surgical infrastructure.

China's Percutaneous Puncture Surgical Robot Market Size, 2020-2032E



Source: NMPA, Expert Interview, Annual Report, CIC

China's Competitive Landscape of Percutaneous Puncture Surgical Robot Market

The competitive landscape of China's percutaneous puncture surgical robot market remains in its early stage of development, with a limited number of approved products and emerging participants. As of the Latest Practicable Date, a total of 13 companies and 17 systems have obtained regulatory approval, covering major clinical applications in the lung, abdomen, and prostate. Among domestic manufacturers.

Competitive Landscape in China, by Number of Trial Installations, in 2024

Rank	Name	Description	Number of Trial Installations
1	**Company A**	Founded in 2018, headquartered in Guangdong, the company focuses on artificial intelligence and robotic control as its core technologies. The company specializes in the R&D, and industrialization of puncture diagnosis and treatment technologies, as of the Latest Practicable Date, it had obtained 4 NMPA registration certificates for percutaneous puncture surgical robots.	**26**
2	**Our Company**		**20**
3	**Company B**	Founded in 2015, headquartered in Shanghai and listed in 2021 on HKEX, the company's product portfolio covers laparoscopic, orthopedic, pan-vascular, natural orifice and percutaneous puncture surgical robot. As of the Latest Practicable Date, it had obtained 1 NMPA registration certificate for percutaneous puncture surgical robot.	**8**
4	**Company C**	Founded in 1999, headquartered in Shenzhen, the company focuses on manufacturing and development of interventional medical devices for cardiovascular, cerebrovascular and peripheral vascular diseases. As of the Latest Practicable Date, it had obtained 1 NMPA registration certificate for percutaneous puncture surgical robot.	**5**
5	**Company D**	Founded in 2019, headquartered in Shenzhen, the company is engaged in the R&D of medical surgical robots. As of the Latest Practicable Date, it had obtained 1 NMPA registration certificate for percutaneous puncture surgical robots.	**5**

Source: Expert interview, CIC

In China's percutaneous puncture surgical robot market, product differentiation primarily centers on integration level, automation capability, and procurement cost. Among the players, our company stands out as the only image-guided percutaneous puncture surgical robot that integrates CT imaging technology with intelligent sensing architecture.

Future Trends in Percutaneous Puncture Surgical Robot Market

- ***Technological Advancement Driving Precision and System Integration***

Continuous innovation in imaging, robotics, and intelligent algorithms is reshaping percutaneous surgical robots toward higher precision, automation, and interoperability. With sub-millimeter positioning accuracy and flexible multi-degree-of-freedom control, robotic systems significantly reduce the risks associated with manual puncture operations while improving surgical consistency. Future systems are expected to achieve deeper integration with hospital information systems and imaging platforms, enabling real-time data sharing, remote collaboration, and intelligent clinical decision support. These advancements will promote the evolution of image-guided interventions toward standardized, data-driven, and automated surgical ecosystems.

- ***Increasing Supported by Policy and Clinical Validation***

Robot-assisted puncture technology has developed steadily since 2014, driven by continuous technological innovation and expanding clinical evidence. Although still in its early stage of clinical application, the technology's advantages in enhancing accuracy, simplifying procedures, and reducing complication risks are accelerating adoption across tertiary and primary hospitals. In parallel, its clinical scope is gradually expanding from diagnostic biopsies to a broader range of image-guided ablation and minimally invasive therapeutic procedures. With ongoing policy support for medical device innovation and interventional standardization, penetration rates are expected to rise steadily over the coming decade.

Entry Barriers of Percutaneous Puncture Surgical Robot Market

- ***Technical and Intellectual Property***

The market features high technical complexity and strong intellectual property protection. Developing a clinically reliable system requires the integration of precision robotics, multi-modal imaging, and AI navigation, demanding deep interdisciplinary expertise. Established players' dense patent portfolios further raise the R&D threshold and increase the cost and difficulty for new entrants.

- ***Regulatory and Clinical Validation***

As a high-risk medical device, regulatory approval requires lengthy clinical evaluation to verify safety and efficacy, leading to long development cycles and high compliance costs. Clinical adoption is equally challenging, as hospitals and physicians rely on extensive clinical data and cost-effectiveness evidence before accepting new systems.

- ***Commercialization and Operations***

Successful commercialization depends on capabilities in precision manufacturing, supply-chain management, and post-installation service. The need for continuous doctor training, system integration, and maintenance create high switching costs for hospitals, allowing established players with comprehensive operational systems to maintain long-term competitive advantage. In the US and EU, hospital equipment procurement typically relies on more standardized value-assessment frameworks and long-term service agreements, whereas in China, commercialization more often depends on demonstration cases in leading departments and the gradual diffusion of best practices from benchmark hospitals to a broader network.

- ***AI Capability and Data Accumulation***

The development of AI-assisted navigation algorithms depends on long-term accumulation of clinical data and system feedback. Through iterative learning, established players continuously improve targeting accuracy and workflow intelligence, forming a self-reinforcing advantage that is difficult for late entrants to replicate. In addition, physicians' long-term familiarity with specific robotic platforms creates strong brand dependency, further increasing substitution barriers. Also, compared with the US and EU, China's stricter data governance and access controls make it more difficult for new entrants to accumulate large-scale clinical datasets and achieve rapid breakthroughs in AI performance.

SOURCE OF INFORMATION

We engaged CIC, an independent market research and consulting company that provides industry consulting services, commercial due diligence, and strategic consulting, to conduct detailed research on and analysis of the percutaneous puncture surgical robot market in China and globally. We have agreed to pay a fee of RMB1.0 million to CIC in connection with the preparation of the CIC Report. We have incorporated certain information from the CIC Report into this section, as well as into "Summary," "Business," and elsewhere in this document to provide potential [**REDACTED**] with a comprehensive presentation of the industries where we operate.

During the preparation of the CIC Report, CIC conducted both primary and secondary research, and gathered knowledge, statistics, information, and insights on industry trends within the target research markets. The primary research involved interviews with key industry experts and leading industry participants. The secondary research consisted of analyzing data from various publicly available sources, such as the National Bureau of Statistics.

The CIC Report was compiled based on the following assumptions: (i) the overall social, economic, and political environment in China and globally is expected to remain stable during the forecast period; (ii) the economic and industrial development in China and globally is likely to maintain a steady growth trajectory during the forecast period; (iii) key industry drivers are likely to propel the percutaneous puncture surgical robot market in China and globally forward during the forecast period; and (iv) the market will not be dramatically or fundamentally affected by any extreme force majeure events or unforeseen industry regulations.