Neurosurgical Care in Italy: A Comprehensive Review and Lessons for High-Income Nations

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Italy's neurosurgical system provides valuable insights for developed nations seeking to optimize care delivery while managing aging populations and resource constraints. With approximately 1000 neurosurgeons (1.69 per 100 000 people) distributed across 141 neurosurgical divisions, Italy delivers equitable access through its National Health Service while demonstrating exceptional cost-effectiveness, with procedures averaging $11 907 compared with $24 754 in the United States. Italy has integrated cutting-edge technologies including virtual and augmented reality applications that reduce surgical errors by up to 36% in mixed-reality neuronavigation, alongside virtual reality–based rehabilitation programs improving cognitive function and pain management. The system's 77 active multidisciplinary teams optimize complex cases in neuro-oncology and pediatric neurosurgery, supported by systematic care improvements including the Homogeneous Waiting Group approach for clinical prioritization, digital preassessment tools, and tele-neuro-rehabilitation programs that reduce hospital readmissions. Structured follow-up care with standardized 3 to 4 month intervals demonstrates superior early recurrence detection compared with variable international practices. This report will delve in greater detail Italy's innovative approach to neurosurgical procedures, training, and educational methodologies that are producing better outcomes for patients and health care professionals.

KEY WORDS: Cost-effectiveness, Digital health, Health systems, Italy, Minimally invasive surgery, Neurosurgery, Telemedicine

Italy has a rich history of contributions to neurosurgery innovation.[1] The country boasts one of the highest densities of neurosurgeons per capita in Europe, facilitated by its publicly funded National Health Service (SSN) ensuring equitable access to innovative neurosurgical care.[2] Italy is a leading country in the field of neurosurgery, with a robust health care system and highly ranked neurosurgery programs, specialized neurosurgical centers, and a high volume of procedures performed annually.[3] These procedures span major neurosurgical categories, including but not limited to carnival, spinal, functional, peripheral nerve, and pediatric neurosurgery. For example, a nationwide analysis of 1.56 million spinal operations using the Italian National Hospital Discharge database showed that spinal procedures increased from 58 369 in 2001 to 97 636 in 2019. With a 67% rise driven by a 420% increase in implant-related procedures.[4] Italy maintains a strong neurosurgical workforce with approximately 1000 neurosurgeons, equating to 1.69 neurosurgeons per 100 000 people.[5] This density is higher than several European countries, including the United Kingdom (0.68 per 100 000) and Norway (1.48 per 100 000).[2] A broader comparison of neurosurgical infrastructure, workforce, costs, and training across selected countries is summarized in Table. This workforce capacity supports Italy's ability

ABBREVIATIONS: BGL, blue-green light; **HWG,** homogenous waiting group; **MRN,** mixed-reality neuronavigation; **XR,** extended reality.

to maintain high procedural volumes across different specialties. Unlike systems where neurosurgical care is highly centralized or privatized, Italy's infrastructure enables an even geographical distribution of specialists, reducing disparities in access.[2] A recent survey of 54 neurosurgical centers in Italy found that each center performs between 300 and 2000 surgeries annually.[16] Italian neurosurgical care is organized across university hospitals, tertiary referral centers, accredited private hospitals, and regional community hospitals, with services distributed relatively evenly throughout northern, central, and southern Italy. Some hospitals specialize more in brain operations, while others focus on spinal or peripheral nerve procedures, showing the decentralized organization of neurosurgical services. For instance, University of Pittsburgh Medical Center Italy states that its neurosurgeons specialize in treating conditions of the brain, spinal cord, spine, and peripheral nerves, showing a broad but subspecialized service model.[17]

Given these trends, Italy's neurosurgical infrastructure provides valuable lessons for other developed nations. The country's proactive approach during the COVID-19 pandemic, which included the rapid retraining of neurosurgeons to support critical care and frontline roles, showcased a model of adaptability in crisis situations.[18] This flexibility was illustrated by the structure of Italy's regional health care systems, particularly in Lombardy, the first European region hit by COVID-19 where a longstanding public-private delivery model allowed for rapid expansion of clinical capacity. During the initial surge, 12 306 hospital beds were converted for COVID-19 care, 40% of which were supplied by accredited private hospitals, and intensive care capacity increased by 95%, reaching 1755 intensive care unit beds with 28% provided by private facilities. Private providers also conducted 62% of Severe Acute rESpiratory Syndrome Coronavirus 2 tests and administered more than 2.6 million vaccine doses in 2021, substantially boosting regional diagnostic and vaccination capacity.[19] Similarly, the country's investment in technology has enhanced precision in neurosurgical procedures, reducing recovery times in the geriatric population.[2]

PATIENT JOURNEY AND EXPERIENCE OF NEUROSURGERY

In 2000, the homogenous waiting group (HWG) approach was first developed and implemented by the Italian Ministry of Health to create a streamlined clinical prioritization and referral process, including in surgical procedures.[20] HWGs represent priority categories created after general practitioner and specialist collaboration to identify sets of outpatient services and define basic criteria for prioritizing patients' access, as opposed to outpatient care on a "first-come-first-serve" basis which resulted in excessive waiting times. In neurosurgery and for all non-traumatic brain injury and traumatic brain injury-related cases, acute imaging is performed, usually after an initial assessment, to determine whether surgical treatment is required. For nonurgent cases, the preoperative pathway clinically incorporates neuroimaging and consultations with neurosurgeons to construct treatment approaches with potential telemedicine for follow-ups. Further steps have recently been taken to reduce waiting lists in addition to HWG implementation, with the growing inefficiencies of the preoperative evaluation outpatient clinic (defined as "Pricovero" in Italy).[21] In 2020, the conference between the Italian state and regions issued the "guidelines for the governance of the planned surgical patient path," defining the surgical patient pathway; prericovero planning represents a phase of this process, and the

TABLE. Neurosurgical Infrastructure and Residency Duration in Italy Compared with Other Countries

Category	Italy	Spain	United States	United Kingdom
No. of neurosurgical units	150 units[6]	50 units[7]	5700+ units[8]	30 units[8]
Population per neurosurgical unit	7 per 250 000 citizens[9]	2 per 250 000 citizens[10]	3 per approximately 250 000 citizens[7]	1 per 250 000 citizens[8]
Total neurosurgeons	1305 surgeons[11]	157 surgeons[10]	Fewer than 3700 neurosurgeons[7]	384 neurosurgeons[8]
Length of hospital stay	3-4 d[12]	8 d and >3 wk[13]	6.5 d[7]	6.4 d[8]
Minimally invasive neurosurgical procedures	3250-8380 cases[10]	1123 procedures	52 949 procedures[7]	1935 procedures[8]
Average cost of a neurosurgical spine procedure	$0 (public)/$6000-$12 000 private[10]	~$3500 (public)/$12k-$21k private	$50 000-$80 000[7]	$0 (NHS)/$5000-$8000 private[8]
Neurosurgical residency length	5 y[6]	5 y[14]	7 y[15]	8 y (2 y of core surgical training followed by 6 y of neurosurgery specialty training)[6]

NHS, National Health Service.

guidelines described are currently integrated through the use of digital health and telemedicine.[21] These tools are most effective in the preassessment preceding the preoperative anesthetic evaluation and can be classified as self, nonself, or hybrid. Self preassessment involves various digital methods of collecting information from the patient themselves such as electronic questionnaires, while non–self-assessments use the exchange of documents shared electronically and asynchronously between health care professionals. Hybrid methods, such as telephone screenings, take place synchronously between patients and health care professionals.[22] The utilization of digital health technologies in the self, nonself, and hybrid preassessment expedite the surgical scheduling process in prericovero.

In addition, the growing adoption of health apps and wearable devices in Italy contribute to enhancing patient engagement and improving postoperative outcomes in neurosurgery. A survey of Italian health care associations found that these digital tools are increasingly being used to support patient self-management and engagement in their own care.[23] The use of health apps and specific wearable neurosurgical rehabilitation devices in Italy is expected to improve postoperative rehabilitation by continuous monitoring of vital signs related to intracranial pressure variation and heart rate which are important to identify early stage post-surgical complications. In particular, Italy has started using several proven wearable devices during neurosurgical rehabilitation. A few examples are inertial-sensor motion trackers used to monitor gait, balance, and cervical range of motion after spine or cranial surgery. The TWIN lower-limb exoskeleton was additionally developed by the Italian Institute of Technology, and it was used in centers such as Fondazione Santa Lucia Istituto di Ricovero e Cura a Carattere Scientifico in Rome for neurorehabilitation after spinal or brain injuries.[24] The observed technologies could enable patients to adhere to individually prescribed rehabilitation methods resulting in fewer complications, better functional results, and lower consumption/cost of health care resources.[25]

MINIMALLY INVASIVE SURGICAL INNOVATIONS

Italy boasts many advancements in spine and brain surgery dating back to the 20th century, as well as more recently for minimally invasive techniques and advanced surgical tools. One example being the adoption of full-endoscopic transforaminal lumbar discectomy, evaluated in a 200 patient Italian group treated between October 2018 and March 2023. After the surgical learning cure was completed, postoperative satisfaction reached 94% with only 6% of patients reporting dissatisfaction at 30 days. Transient paresthesia occurred in 33.5% of cases but resolved without long-term deficit. The study also identified predictors of poorer outcomes, including degenerative listhesis (odds ratio 4.8) and severely degenerated discs (odds ratio 8.7), while severe foraminal stenosis was associated with a lower risk of failure. These findings support full-endoscopic transforaminal lumbar discectomy as a safe and effective minimally invasive option within Italian neurosurgical practice.[26]

Research centered around evaluating the frequent minimally invasive procedures, with 3110 such operations completed in Italy in 2022 alone.[27] These neurosurgical procedures mainly included endoscopic endonasal approaches for pituitary and skull base tumors, percutaneous procedures for trigeminal neuralgia.[28]

Robotic systems have become an important part of Italy's minimally invasive surgery portfolio as well. They enable the surgeon to perform procedures through tiny, 1 to 2 cm incisions. Surgeons at the Verona Pancreas Unit use the da Vinci Xi HD system to perform complex pancreatic resections, ranging from left pancreatectomy (sometimes with splenectomy). In Milan, the Policlinico di Milano was the first public hospital in the country to introduce the Versius surgical robot, making a turning point in access to robotic surgery.[29]

In addition, these minimally invasive surgeries have been practiced by Italian neurosurgeons working in conjunction with multiple hospitals to improve the safety of removing colloid cysts with the usage of endoscopy. Between 1994 and 2005, a total of 61 patients with colloid cysts of the third ventricle underwent neuroendoscopic treatment across 11 neurosurgical centers in Italy. The cysts measured between 6 and 32 mm in diameter. To treat this while trying to minimize the damage that would have been caused because of the removal requiring a large invasive procedure which can be risky, a flexible endoscope was used in 34 cases, a rigid endoscope in 21 m and both instruments in 6. The procedure involved cyst fenestration, aspiration of colloid material, coagulation of the inner cyst wall, and in some instances, excision of the capsule. The outcomes resulted in postoperative hospital stays that were 6.7 days, which is a short recovery time. In the early postoperative neuroimaging revealed a cyst residue in 36 cases (mean diameter 4.3 mm) and a result of 2 complications (3.2%). Overall, this endoscopic advancement performed by an Italian neurosurgical study demonstrated a safe and effective approach to the treatment of colloid cysts for patients globally.[30]

A related Italian series also demonstrates the safety and efficacy of minimally invasive surgery in complex thoracolumbar disease. In this cohort, 45 elderly patients (mean age 73 years; range 65-89) were treated at Policlinico G. Rodolico University Hospital in Catania for osteoporotic vertebral fractures (n = 24), degenerative spondylolisthesis (n = 15), or lumbar canal stenosis with instability or de novo scoliosis (n = 6). Procedures included percutaneous pedicle screw fixation, m-open transforaminal lumbar interbody fusion, and 6 receiving fenestrated screws with cement augmentation. Despite the advanced age and comorbidity burden of the cohort, postoperative outcomes were favorable: Mean visual analog scale scores improved from 9 to 4 and Oswestry disability index decreased from 76.33% to 38.15%. Follow-ups ranged from 5 to 59 months (mean 32 months), during which only 3 postoperative complications were reported, and no patient developed any new neurological deficits. These findings show minimally invasive surgery as a safe, feasible, and function-preserving choice for elderly patients with degenerative or traumatic thoracolumbar instability.[31]

VIRTUAL AND AUGMENTED REALITY APPLICATIONS

Regarding technology, Italy is actively integrating virtual reality and augmented reality into neurosurgery, enhancing precision, training, and patient outcomes.[32] Augmented reality and virtual reality are transforming neuronavigation in Italy, particularly for complex vascular interventions, by providing 3-dimensional visualization of anatomic structures. Italian neurosurgeons have used in-house software using commercial Rhinoceros 3-dimensional programming models for screw placement in the lumbar pedicle, allowing for precise surgery planning and execution.[33,34] With this being said, of the limited empirical data, recent in vivo studies suggest presurgical planning with extended reality technology in neurosurgery: a surgery-based study describing a preliminary experience in Italy. The use of extended reality is incorporated in many forms and is used through virtual reality. The authors of the research aimed to assess how Italian neurosurgical trainees perceive extended reality (XR) technologies and to measure their influence on the learning curve of a small cohort of residents from multiple Italian institutions. A 20-item survey was administered to a pilot group of 5 trainees at the Bambino Gesu Children's Hospitals in Italy to gather preliminary data over a 3-month period. As a result, most participants viewed XR as effective in replicating real surgical anatomy and trajectories. The pilot group of 5 trainees also reported steadily increasing confidence in managing surgical cases. This preliminary experience indicates that XR can meaningfully support neurosurgical training, with perceived benefits even in settings where these tools are not routinely available. Larger studies in Italy are needed to confirm and standardize these findings.[35]

ADVANCED NEURONAVIGATION AND PRECISION SURGERY

Further research by Italian neurosurgeons has focused on optimizing the practical application of advanced neuronavigation systems like mixed-reality neuronavigation (MRN). A key challenge identified and addressed is the interference of standard operating room lighting with MRN systems. To overcome this, the use of blue-green light (BGL) was shown to be a highly effective solution, as detailed in phantom-based experiments comparing MRN with magnetic neuronavigation conducted by research groups in Italy. This innovation directly tackles a major hurdle: Standard operating room white light often makes MRN holograms nearly invisible, hindering their use and preventing clean data collection. BGL significantly enhanced navigational precision in MRN, reducing the average error for both senior and junior neurosurgeons.[36] While the average recording time using BGL was slightly longer (128 seconds for senior operators and 145 for juniors, compared with 119 and 130 seconds, respectively, with normal lighting), this minor increase is a small trade-off for the substantial benefits of a clear hologram visibility and a significant boost in navigational accuracy.[36] A team of neurosurgeons at the Carlo Besta Neurological Institute in Milan developed tailored cortical resections, which involves the removal of the epileptogenic zone in the brain, an area responsible for seizure activity.[37] The surgery is tailored to the individual patient's needs, guided by invasive monitoring techniques like stereo-electroencephalography. The goal is to resect the epileptogenic zone while preserving critical brain functions.[37]

REHABILITATION SERVICES AND FOLLOW-UP CARE

Italy's neurosurgical postoperative care system has demonstrated significant progress in enhancing patient outcomes through effective rehabilitation services and structured follow-up care. One example being the introduction of tailored follow-up pathways.[38] For instance, a study on the follow-up care in an Italian center by Silvaggi et al found among those with glioma II who had a second surgery, follow-up consisted of 4 visits per year (average every 3 months) and 3 exams per year (average every 4 months), with ranges from 2 to 7 months for examinations and 2 to 8 months for visits. This structured approach contrasts with practices in other countries: In the United Kingdom, a nationwide study of 31 neuro-oncology centers showed varying follow-up practices, with only 71% performing routine MRI at treatment completion and 81% maintaining 3-month follow-up intervals.[39] Follow-up protocols in the United States show variation between institutions, lacking the standardized approach seen in Italy's system.[40] Furthermore, a study conducted in Milan emphasized the importance of personalized follow-up care pathways for patients with high-grade gliomas.[38]

COST-EFFECTIVENESS AND EFFICIENCY COMPARED WITH OTHER EUROPEAN COUNTRIES AND THE UNITED STATES

In assessing the cost-effectiveness of neurosurgery in Italy, the Italian National Health Service (SSN) presents an intriguing model, especially when compared with other European nations and the United States. While Italy's overall health care spending is lower—9.3% of gross domestic product in 2022, compared with 12.8% in the United States—the country maintains high standards in health care outcomes.[39]

Italy's health care system efficiently uses resources, resulting in relatively low costs for medical procedures and hospital stays. Factors such as reduced administrative overheads, lower malpractice insurance costs, and streamlined resource allocation contribute to these savings.[41] While specific neurosurgical cost data are limited, general medical procedures in Italy are often more affordable than in the United States.[41] Specifically, the average price for neurosurgery performed in the United States is 24 754 and Italy is 11 907 USD (lowest 399 USD, highest 27 676 USD). Minimally invasive surgery is heavily used in Italy, although its adoption varies by region and surgeon preference. This approach resulted in cost savings of €973 per procedure and improved health-related quality of life by 0.04 quality-adjusted life-years over 2 years.[42] Treatment to the brain tumor in Italy costs on average 17 694 USD, ranging between 12 710 and 30 380 USD, with its identical counterpart in the United States costing between 50 000 and 150 000 USD. The cost of neurological rehabilitation is equal to 2998 USD, ranging from 50 to 8225 USD, with its US version costing 46 000 USD.[10,43,44] Despite these challenges, Italy's neurosurgery sector remains competitive within the European context, delivering high-quality care at lower costs compared to the United States.[13] Importantly, direct comparisons between Italy and the United States must be interpreted cautiously because the systems are fundamentally different in several areas. The Italian SSN is built on a streamlined three-tier model physicians (∼4.0 per 1000 population), nurses (5.8 per 1000), and operatore socio sanitario/nurse-aids (2-3 per 1000), each with clearly defined scopes of practice. These structural differences, not simply in efficiency, explain much of the spending gap.

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COMMENTS

The authors present a comprehensive analysis of neurosurgery care in Italy and compare its cost-effectiveness with other advanced health care systems. Italy plays an important role in advancing neurosurgery, and its unique health care system is foundational to this. The SSN (the Italian health care system) is mainly funded by taxpayers but is also supported by insurance-based and purely private systems that work in tandem to offload increasing demand. In this context, the field of neurosurgery has flourished, and Italy possesses one of the highest numbers of neurosurgeons per capita in the entire Western world. This ensures a widespread presence of highly specialized doctors across the territory, resulting in one of the most broad-based and equitable coverage models in Europe. Moreover, thanks to this system and the funds provided by the European Union, Italy has always positioned itself as an innovator in the field of neurosurgery, spanning from minimally invasive to robotic and robotic-assisted procedures.

The authors did an outstanding job in underlining all these aspects and deserve praise for their efforts.

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