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Historical vignette

Neuroanatomy and cadaver dissection in Italy: history, medicolegal issues, and neurosurgical perspectives

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✓Despite the significant Italian tradition of important anatomical studies, an outdated law historically influenced by the Catholic church restricts the use of cadavers for teaching and scientific purposes. The object of the present paper was to trace the historical evolution of the Italian anatomical tradition, particularly neuroanatomical studies, in relation to the juridical regulations on the use of cadavers today. Special attention was paid to the opportunities offered to neurosurgery by using cadavers and to the scientific and social issues in neurosurgical training in the twenty-first century. Considering the new Common European Constitution, the authors advocate a political solution from the European community to improve the quality of training in the disciplines with a social impact such as neurosurgery.

Key Words • cadaver dissection • neurosurgical education • neuroanatomy • history of neurosurgery

The Italian passion for anatomy and physiology originates in the fourteenth and sixteenth centuries with the cadaveric dissections and studies conducted by Mondino de Liuzzi, Leonardo da Vinci, Andreas Vesalius, and Giovan Battista Morgagni.[10,28] Cadavers represented a unique instrument for understanding anatomy, physiology, and pathophysiology. In neurosurgery, as in other disciplines whose surgical anatomy is extremely complex and the use of microsurgical techniques is indispensable, rigorous theoretical and practical knowledge of surgical anatomy and dissecting techniques are mandatory. Despite the significant Italian tradition of important anatomical studies, an outdated law together with the moral influence of the Catholic church restricts the use of cadavers for teaching and scientific purposes. The object of the present report was to trace the evolution of Italian neuroanatomical studies in relation to the juridical regulations for the use of cadavers. Special attention was given to the social issue of current neurosurgical training in Italy.

Historical Considerations

Influence of Christianity on the Teaching and Study of Anatomy

Through the actions of Costantine, who in AD 313 affirmed Christianity as the state religion, and Theodosius, whose decree in AD 392 demanded the closure of all temples and prohibited any pagan cult, one perceives the gradual ascent of a doctrinal system that authoritatively laid down social, political, and institutional rules based in Christianity.[10] The human body acquired sacredness because of its image and resemblance to God, its function as the bearer of the soul, and its resurrection entailed a reunion with God on the day of justice. The diffusion of these laws to the Christian Roman Empire gave way to the decline of the Alexandrian School, where during Ptolemy's office doctors such as Praxagora, Herophilus, and Erasistratus had conducted the first precious human anatomophysiological studies, dissecting cadavers and performing vivisections on those condemned to death.

Influence of Galen on Medical Schools in the Newborn Universities

Medicine, and consequently anatomical understanding, is referred to Galen's work (summa of all pagan medical knowledge) performed in the second century after Christ.[13–16,18,28] Galen gained an extensive medical education in Pergamon, Smyrna, Corinth, and Alexandria. In Pergamon as the gladiators' doctor, he acquired an accurate understanding of wounds, peripheral nerves, and cranial traumas in humans, and he dissected animals that had been sacrificed in the arena. On relocating to Rome he continued his dissections in monkeys and pigs, defining their anatomy and paying particular attention to the nervous system. He specifically focused his dissections on the cerebral vascularization (he describes the vein in the brain that would later bear his name), and he studied the cranial nerves, spinal nerves, and traumatic effects of the spinal cord and peripheral nerves.[13,15,28] One must always remember that Galen never dissected human bodies and that his anatomical knowledge was based on animal dissections only.[13,14,18]

Born of Modern Medical Schools in Italy: Importance of Dissecting Cadavers in Learning Anatomy

In the thirteenth century anatomical studies were favored by the Emperor Federico II, and his attitude strengthened the tradition of the medieval medical school of Salerno, ordering that only those with a diploma (degree) from this same school could practice medicine.[6,12,20,26] Federico II was the first to issue a decree that authorized cadaver dissections and obligated all surgeons to study human anatomy in cadavers.[12,20,26] It is interesting to see how the different popes during this period with their various attitudes toward cadaveric dissections influenced the study of anatomy (Table 1).

In 1316 Mondino dé Luzzi (Bologna, 1276–1326) was granted permission to introduce and dissect a cadaver in the lecture hall for medicine at the Studium of Bologna. In that period, the standard reference was still the galenic text in which the human body is considered of secondary importance, to such an extent in fact that the objective differences between the anatomicophysiological descriptions of Galen and the observations regarding the cadaver are portrayed as presumed morphological transformations and therefore also physiological.[10–12,20,26] Mondino dé Luzzi established an accurate technique for dissecting the cadaver (placed supine on the table), starting from the abdomen and moving toward the thorax and finally reaching the head, which is considered the noble part of the human body because it contains the brain, or intellectual core.[10–12,26]

In the majority of Italian universities dissections were practiced during Carnival, mostly on deceased women's bodies because of the popular belief at the time that women had no souls. January and February, when Carnival took place, are the coldest months of the year and are therefore ideal for the preservation of cadavers. Furthermore, one must consider the symbolic significance of Carnival—its pagan origins that legitimized transgressive behavior, the liberation and manifestation of instincts, and the upheaval of social conventions—so that contact and manipulation of the cadaver, even if breaching the sacredness of the body, found cultural justification.[6]

Following Mondino dé Luzzi's tracks,[10] didactic medicine began to contemplate the body as a tool to further understand anatomical texts and to pay more attention to the cadaver and thus develop anatomical notions. The contributions of Italian authors as well as foreign anatomists who worked for Italian universities in the study scientific anatomy were based on cadaveric dissections and were very relevant, particularly in the field of neuroanatomy, as summarized in Table 2 and represented in Figs. 1 to 3.[6,27,32,34,39,42–44,46]

Juridical and Religious Laws Arbitrating Cadaveric Dissections in Italy: Evolution of the Juridical Concept of the Cadaver in the Twentieth Century and the Influence of the Catholic Doctrine

Juridically, the word "cadaver" means a dead human body, which implies the complete and irreversible loss of every essential function of the person, of its organs, tissues, and cells. The jurisprudential concept of the cadaver in Italy includes all the human remains that could provoke a sense of pity toward the deceased, that is, the head, limbs, hands, and feet, because these remains by their entity, nature, and characteristics generate the idea of a human body. Paradoxically, the bowels, heart, and lungs could be excluded as not easily catalogued.[9,17,33,36] The Christian belief in the resurrection of the body, with the eternal unification of the body and soul after Universal Justice, significantly influenced the juridical concept of the cadaver in Italian history. Among the first pages of the Italian penal code there are regulations (which date back to the Fascist period when Catholicism was the state religion) that refer to the repression of crimes against religious feelings, especially pity for the deceased. The aim is to juridically protect individual and collective

TABLE 1

Influence of the popes on cadaveric dissections and the study of human anatomy

Pope	Year, Papal Bull	Description
Boniface VIII	1299, "De Sepolturis"	All forms of mutilation & tampering w/ cadavers, boiling & embalming human bodies (& therefore anatomical dissection) were prohibited apart from those juridical interventions to ascertain the cause of death. This law was intended to stop the trade of cadavers of those killed in the Holy Land at the time of the crusades.
Sixtus IV	1472, "Sistina"	Founded the "Collegium Medicorum Romanum" & recognized anatomy as an efficient tool for practicing & teaching medicine, & thus permitting all Universitary Institutes to perform dissections of cadavers.
Clement VII	1531	Established the Statutes of the Collegium Medicorum Romanum, recognized & again confirmed the importance of anatomical studies & public dissections, placing anatomy in the curriculum studiorum of the Faculty of Medicine.

TABLE 2

Main contributions of Italian scientists to neuroanatomy

Place & Year	Name & Scientific Publication/ Achievement	Main Contribution
Bologna, 1316	Mondino dè Luzzi, first authorized dissection on a human cadaver	established an accurate technique to dissect the cadaver; considered one of the fathers of modern anatomy
Florence, 1490	Leonardo da Vinci, drawings of the human body	provided us w/ an important contribution on ventricles; one of his marvelous drawings, the fruit of his experience after having dissected at least 30 cadavers, proposed the classic ventricular system
University of Padova, 1543	Andreas Vesalius, "De Humani Corporis Fabrica" w/ more than 300 illustrations engraved by the Flemish Van Calcar (pupil of the artist Titian)	distinguished gray matter from white matter & described the corpus callosum, nucleus caudatus, sinus venosus, & optic thalamus
University of Bologna, 1573	Costanzo Varolio, "De nervis opticis," which concerned the anatomy of the brain; a new technique in the dissection of the brain starting from its base	presented new method for the study of the brain; described the hippocampus, cerebral pedunculus cerebri, & valve of Varolius, further studied & identified the arachnoid, brainstem (specifically the pons, which bears his name), real form of the cerebral ventricles, & staff muscle
Hospital of San Giovanni & Hospital of Consolazione Rome, 1705–1722	Antonio Pacchioni, "Dissertatio epistolaris de glandulis conglobatis durae meningis humanae"; "De dura meningis fabrica"	brought attention to the presence of granulation along the large venous sinus, which was then named after him
University of Padova, 1761	Giovanni Battista Morgagni, "De sedibus et causis morborum per anatomen indagates"	described diseases of the head, particularly apoplexies, epilepsy, hydrocephalus, & cerebral abscesses; dissected & analyzed the morphological features & components of the brain; identified the brain as the most important organ for individual specificity & function; attributes to systemic pathological anatomy the role of studying the pathological changes in the anatomy of the organs during a disease & correlating them w/ the patient's symptoms
University of Pavia, 1773 & 1794	Antonio Scarpa, "De structura fenestrae rotundae auris, et de tympano secundario"; "Tabulae nevrologicae ad illustrandam historiam, cardiacorum nervorum, noni nervorum cerebri, glossopharingei et pharingei"	described the anatomy of the semicircular channel, the tympanum as well as the vestibular ganglion; studied the artery & the eye's anatomy & diseases; remembered for the anatomical region of the thigh, which bears his name: the Scarpa triangle
University of Sassari, 1809–1829	Luigi Rolando, "Sulle Cause da cui dipende la vita negli esseri organizzati" (1807); "Saggio sopra la vera struttura del cervello dell'uomo e degli animali e sopra le funzioni del sistema nervoso" (1809); "Ricerche anatomiche sulla struttura del midollo spinale" (1824); "Della struttura degli emisferi cerebrali" (1829)	after studying the sulcus fissures & gyri, indicated their regular repetition in dissected brains; 1812, wrote an experimental document that showed the function of the cerebellum; regarded the cerebellum of major importance in determining not only the regulation but also the strength of movement; described the "substantia gelatinosa" & deduced that nervous structures are connected in a network of nervous fibers linked by electrical impulses
University of Pavia, 1906	Camillo Golgi, Nobel Prize	revolutionized study of nervous system, w/ silver salt impregnation & identified the cytoplasm of cells w/ the Golgi device;* contributions of this Italian histologist enabled us to understand the microscopic structure of cerebral tissue

* Grmek, 1993.

feelings (religious respect for the dead) as an expression of an ethical and social force, as a preserver and guarantor of civilization.[5,9,12,17,36] Specifically, the old Article 413 of the penal code states that whoever dissects or uses a cadaver or part of a cadaver for scientific or teaching purposes is punishable by law.

In correspondence with the historical religious evolution, another important and determinant factor on the limitations for the use of cadavers is that tied to endemic prevention that characterized the public health during the nineteenth and twentieth centuries; protection of the dead entailed the protection of the public health more than pity and respect.[6]

Hence, the religious and historical mentality have deeply influenced the current Italian laws.

Discussion

In what cases are cadaver dissections permitted? An autopsy not only plays a cardinal role in forensic medicine but is also of extreme importance for learning anatomy. However, the refinement of surgical skills, particularly the microsurgical techniques in neurosurgery, often is not possible during this procedure. In what way can an autopsy help surgical training?

Italian law makes a distinction between judicial autopsies and diagnostic autopsies.[5,9,17,36,38] In the case of a judicial autopsy, which is used to obtain evidence of a crime, students or residents seldom can participate and cannot use these opportunities to train for surgery; such participation could compromise the confidentiality of the criminal investigation itself as well as the collection of evidence.[5,9,17,36,38] Diagnostic autopsies are different because they are used to solve scientific problems, the secrecy required is more relaxed because no criminal investigation is associated with it, and both students and residents may assist as long as they respect the laws on privacy.[5,9,17,36,38] Diagnostic confirmations

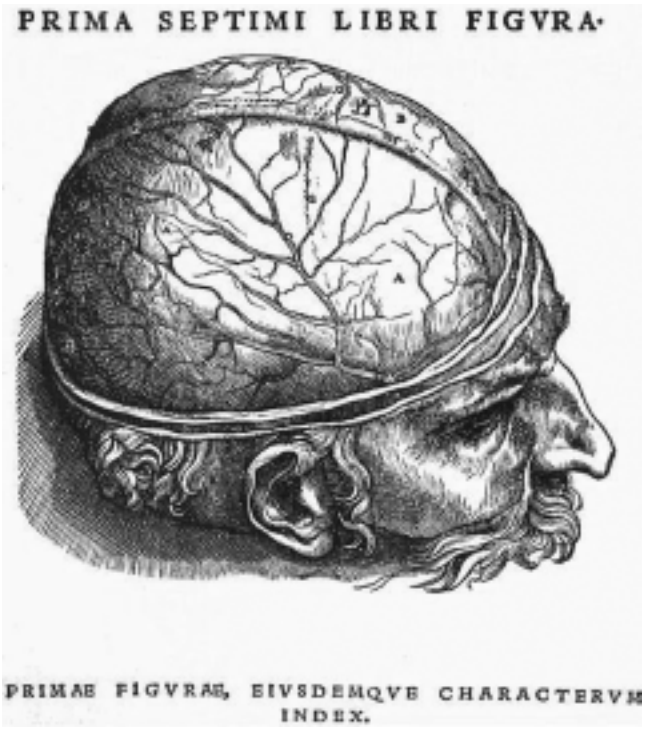

FIG. 1. Drawing produced by Van Calcar, illustrating the vascular supply by the middle meningeal artery and its collateral and terminal branches. The superior sagittal sinus is also evident. From Vesalius A: De humani corporis fabrica, Basileae, 1543.

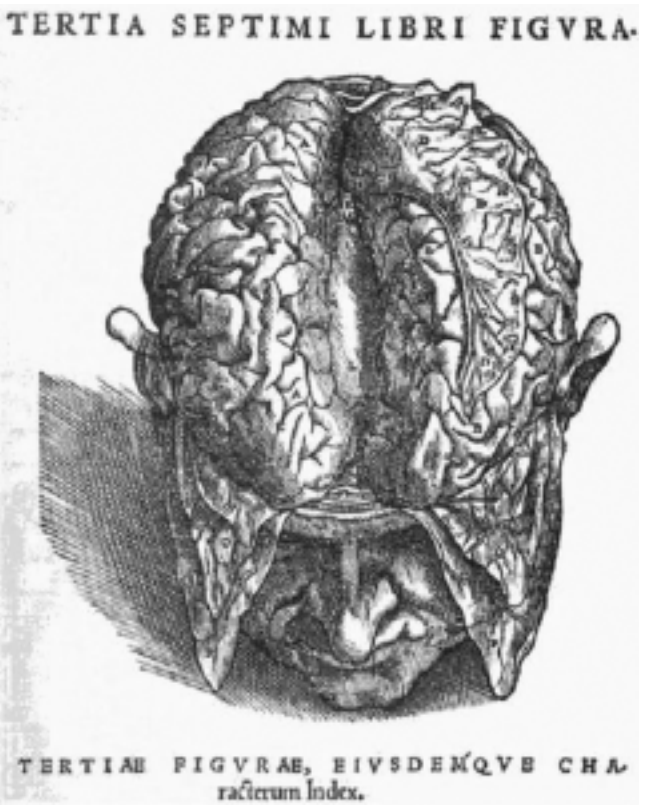

FIG. 2. Drawing produced by Van Calcar, showing the entire cerebral cortical surface after opening the dura mater and the archnoid. The interhemispheric fissure is widened after the removal of the superior sagittal sinus. From Vesalius A: De humani corporis fabrica, Basileae, 1543.

are conducted by an anatomopathologist and/or a forensic pathologist who directs the operation and performs the most important dissections, but nothing prohibits other doctors from performing other dissections under the anatomopathologist's direction. In these cases there are more possibilities for residents to learn surgical technique.[5,9,17,36,38]

On the whole, an autopsy is not an ideal procedure for microsurgical training of a neurosurgeon for the following reasons: 1) There is little time at disposal. 2) Microsurgical dissections require microscopes and neurosurgical instruments (drill, craniotome, and self retractors), which are not commonly used during an autopsy. 3) A dissection cannot overrule a diagnostic investigation, and so autopsies are limited to only those areas linked to the death of the cadaver. Besides autopsy and organ transplantation,[9] the only exception to this regulation is if a person voluntarily agrees via a complete written consent form to donate (selling is severely punished in every case) his or her body for scientific purposes on death.[9] There are even fewer opportunities to perform dissections on cadavers if we consider that unclaimed bodies cannot be dissected, with the exception of very few cases.[9] Frequently, as reported by British authors, the bodies of the newly deceased are used for teaching purposes without informed consent from the decedent's relatives, causing medical, legal, and ethical problems.[2,3,7,17,19,22,24,27,33,35,37,41]

As for the mode and manner of explaining consent, the debates in Anglo-Saxon nations are heated, as opposed to the situation in Italy where there seems to be little interest. Moreover, and also in contrast to Italy, in several countries such as the US, the United Kingdom, France, and Austria, universities and schools of medicine have their own programs for the donation of bodies, with serious strategies for making the public aware of the importance of cadavers for research and learning in medicine.[1–3,5,7,17,19,24,29,33,35–37,40,47,48] Thus, the possibility of creating laboratories for the dissection of cadavers and training of young surgeons in Italy is almost nonexistent.

Neurosurgical Perspectives in Cadaveric Dissection

The lack of whole or parts of cadavers reduces opportunities to learn anatomical and surgical techniques that may be repeated in the operating theater. Consequently, this difficult learning process depends on the student–teacher relationship (resident–attendant) during surgical operations. In our experience and as already pointed out by other authors,[1,4,31,35,37] the learning of surgical anatomy and technical skills during operations presents the following disadvantages: limited time at our disposal, the surgical anatomical field is restricted and depends on the type of operation, and, most importantly, learning is influenced and limited by the pressure and psychological conditioning on the resident and by the medicolegal responsibilities of the senior surgeon toward the patient. For these reasons surgical training in the

laboratory should be both part of every residency program and a consistently available tool for senior surgeons, for the refinement of the microsurgical techniques necessary to perform the most complex operations (skull base surgery, microvascular surgery, anastomoses, and so forth). Furthermore, experimentation and/or the development of new techniques, surgical approaches, and surgical instruments should be first undertaken in animals, cadavers, and/or anatomical specimens in the laboratory, and subsequently in the patient. Considering the complexity and challenging nature of brain anatomy and surgery, respectively, neurosurgeons are perhaps more interested in the development and improvement of cadaveric laboratories.

Dummies as well as virtual three-dimensional or animal models can be a complement but not an alternative to cadavers in microsurgical training.[1,4,23,25,35,37,39,41] In fact, as reported in the literature, several neurosurgeons have contributed to improvements in the conservation and injection systems of the brain and have recently introduced extracorporeal circulation or created three-dimensional models that perfectly simulate the skull.[1,4,21,23,25,31,35,39,40,45,47,48] A model of the head with unique characteristics recently has been introduced by Aboud, et al.[1]; it provides dynamic filling under pressure of the cerebral vasculature with colored liquid and clear fluid filling of the arachnoid cisterns. The carotid and vertebral arteries in the neck are cannulated, as are the internal jugular veins on both sides. The carotid artery and the vertebral arteries are then connected to a reservoir containing light red fluid, and a pressure of 80 to 120 mm Hg and a pulse rate of 60 bpm is established using a pump. The same is done to the jugular veins, which are connected to a reservoir kept at a pressure between 20 and 40 mm Hg. This model simulates actual conditions in the brain and is perfect for training. It can also be used to create surgical aneurysms and simulate endovascular procedures.

Nowadays, the competition among specialists in the different disciplines (neurosurgeons compared with endovascular radiologists) for the treatment of cerebral aneurysms is high, and so it is vitally important to have expert and trained surgeons to treat these pathophysiologies.[8,30] Data from some studies have shown the difference between results obtained from centers with a high and those with a low volume of aneurysms, as well as for various pathological entities of the skull base or complex operations.[8] As for the controversies on the treatment of aneurysms, investigators in the International Subarachnoid Aneurysm Trial determined that surgical treatment was associated with a higher mortality and morbidity rate, whereas endovascular procedures had a higher percentage of recurrence (recanalization of an aneurysm increases the difficulties of successive treatment) and complications (embolus vessel constriction) in the long run.[30] In contrast, if there is a longer learning curve for the surgical treatment of aneurysms with respect to endovascular treatment (coil embolization), it is also true that with a period of laboratory training on human cadavers or guinea pigs, this process would be shortened. In the future, fewer aneurysms will be surgically treated and so the total volume of this pathological entity will decrease.

For those cases that cannot be treated by endovascular means, the surgical approach will always be necessary. One will face the risk of having complex aneurysms and a surgeon who has dealt with limited pathophysiologies. It is therefore necessary for surgeons to undergo laboratory training on perfused cadavers or experimental models. Such models can be used by endovascular surgeons who frequently collaborate with neurosurgeons in combined teams. Another possibility in the future will be the simulation of surgical operations in cadavers with the aid of neuronavigation systems that can create a patient's pathophysiology in the laboratory specimen (Fig. 4). One could create a computerized archive of artificially perfused specimens (properly prepared as described by Aboud, et al.[1]) and submit them to magnetic resonance imaging. Subsequently, one could select a model whose anatomy resembles that in the patient to be treated (this is possible by merging magnetic resonance images thanks to the ImMerge function, which is currently available in most neuronavigation systems; Fig. 5) to simulate and preoperatively prepare the surgical approach to be performed later.

The public must understand the importance of cadavers for learning surgery and the possible creation of experimental models that simulate the conditions of real operations. Such an understanding would clarify the concept that it is preferable to have surgeons who have performed the most complex operations in the laboratory beforehand than

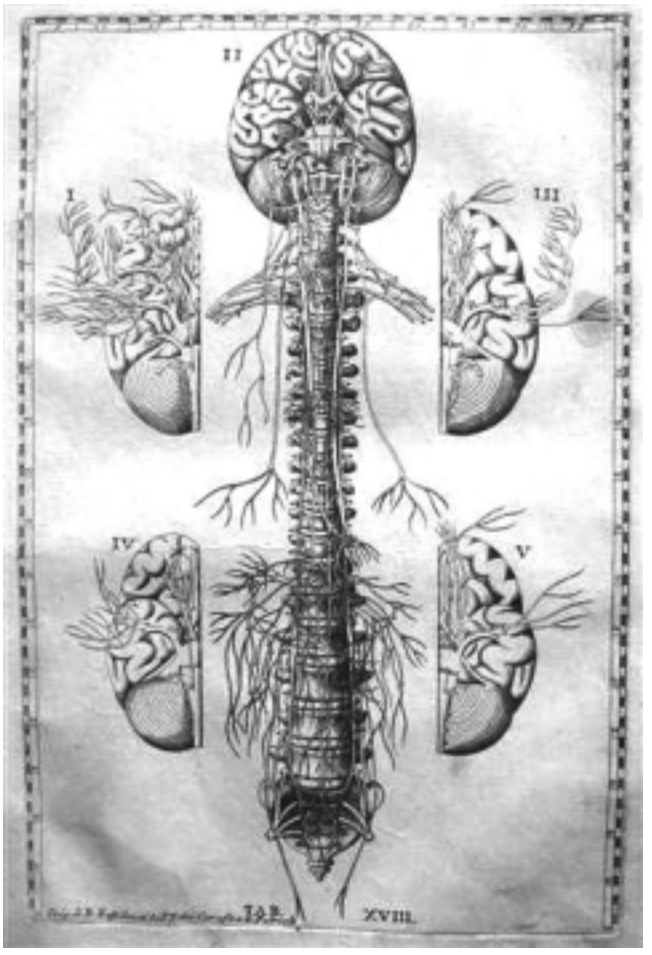

FIG. 3. Illustration by Eustachii showing the central nervous system and the peripheral and cranial nerves. From Petrioli G, Reflessioni anatomiche sulle note de lancisi fatte sopra le tavole del celebre. Bartolomeo Eustachio, Giovanni Zempel, 1740.

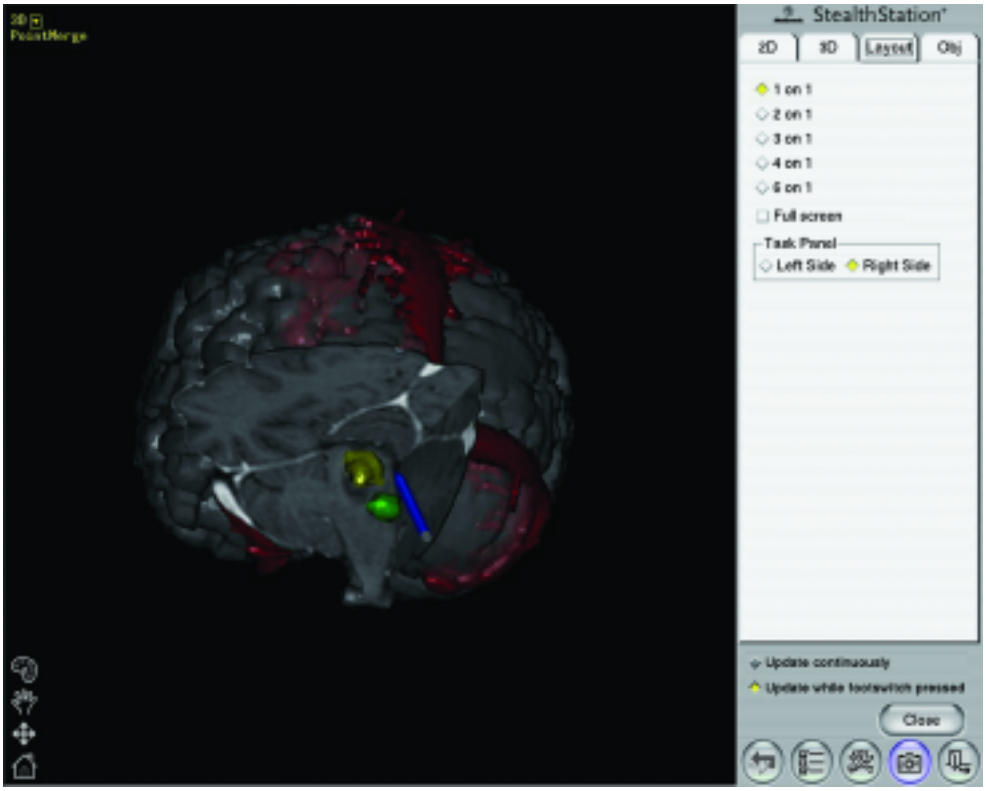

FIG. 4. Three-dimensional model of a human brain adapted from a magnetic resonance image, showing the potential for creating pathophysiologies on a neuronavigator workstation.

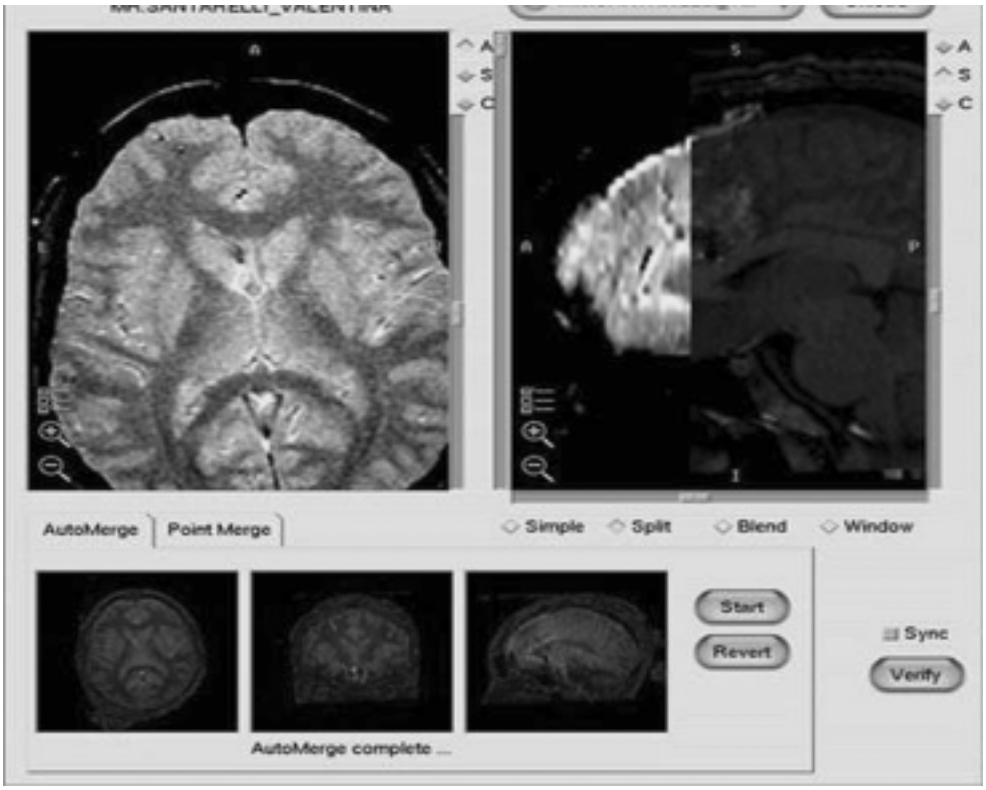

FIG. 5. Screen shot revealing images created with the ImMerge function on a workstation.

to have surgeons performing this same operation for the first time in the operating theater (even if guided by a senior surgeon). Considering the Italian contribution to neuroanatomy and the historical tradition in the dissection of cadavers, it is strange that in the era of microsurgery we have so very few opportunities to perform dissections in anatomical specimens. Although the majority of live workshops on cadaver dissections have been organized in the US and those in that country have mostly contributed to the creation and perfection of anatomical models, France, Austria, Germany, and the United Kingdom have also had a prominent role in developing neurosurgical training in the laboratory.[1,3,4,19,22,31,40,45,47,48] Hands-on courses are also organized in Italy but their numbers and venues are limited because of the various ministerial authorizations and series of bureaucratic procedures that must be followed to circumvent the penal code's ban on dissection of the head. Specimens are prepared outside of Italy and provided for free by Departments of Anatomy at foreign universities and finally returned to the foreign institutions to whom they belong once the hands-on course is finished. Consequently, many of these courses are expensive, very intensive (12 hours per day for 2–3 days in a row), and permit only limited working time (two participants use each specimen). These courses are intended more for the refinement of surgical skills than for learning basic surgical techniques. In addition to those factors related to a course, the real matter is one of establishing a permanent microsurgical laboratory that is always available to residents as a real tool in their continuing education as neurosurgeons.

Conclusions

The use of heads or other anatomical specimens for neurosurgery is important for the following reasons: 1) training of the resident with regard to surgical anatomy, the correct use of instruments (such as the scalpel, microscissors, drills, and microscopes), the surgical approach, and the refinement of vascular microsurgical techniques; 2) simulating the more complex operations and successfully performing such procedures in the operating theater, as well as practicing with the most modern tools such as neuronavigation systems; and 3) conducting practical tests for the evaluation of an attendant's surgical skills (to be considered for promotions in their careers) as well as those of both students and residents (to be considered for admission to residency and fellowship programs).

Despite the Italian tradition of dissection, anatomical, and surgical studies, the creation of a permanent microsurgical laboratory is nearly impossible because of the extreme unavailability of cadavers. This situation is due to a law bound to the Catholic conception of the human body as an inviolable object, which dates back to the Fascist era of the reconciliation between the Italian state and the Catholic church. Considering the new Common European Constitution, we advocate a political solution for the European community to improve the quality of training in disciplines with a social impact such as neurosurgery.

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