Neurological and Architectural Sinuosities: The Niemeyer Brothers

In a family of 7 siblings in Rio de Janeiro, Brazil, 2 of the most remarkable national personalities decided to follow different fields at the beginning of the 20th century. Their life’s work would, however, intersect in at least 2 respects: the quest for innovation and a passion for sinuosity. The achievements of Paulo and Oscar Niemeyer are landmarks in the history of neurosurgery and architecture in Brazil. Among his many innovations in neurosurgery, Paulo Niemeyer first described the transventricular amygdalohippocampectomy in 1957 and introduced the operating microscope to neurosurgery in Brazil in 1971. His brother Oscar became a world-renowned representative of the modern architecture movement, sculpting graceful curves from concrete.

KEY WORDS: Amygdalohippocampectomy, Epilepsy, Modern architecture, Neurosurgical history, Oscar Niemeyer, Paulo Niemeyer

Born in the same family in Rio de Janeiro at the beginning of the 20th century, 2 remarkable personalities pursued different fields. Their careers, however, intersected in at least 2 respects: the quest for innovation and a passion for the exploration of sinuous structures. The achievements of Paulo and Oscar Niemeyer are landmarks in the history of neurosurgery and architecture (Figure 1). We review the historical implications of the brothers’ careers, the similarities of their approaches to problems, the contents of their endeavors, and their remarkable influence on their respective fields.

THE INCIPIENT CAREERS

Paulo Niemeyer

Paulo Niemeyer was born on April 14, 1914, in Rio de Janeiro (Figure 2). He was the youngest of 7 siblings. He graduated from the Medical School of the Federal University of Rio de Janeiro in 1936, an institution more than 200 years old and the first medical school in Brazil. He completed his training in general surgery at the Santa Casa de Misericórdia Hospital of Rio de Janeiro, a philanthropic institution, where he dedicated almost 70 years of his life. Niemeyer performed the first gastrectomy at this institution. In 1938, he performed the first stored-blood transfusion in Brazil.

Initially a general surgeon, Niemeyer gradually switched his interest to neurosurgery in the late 1930s. Surgeries of the sympathetic system, primarily periarterial sympathectomies, were commonly indicated in the management of pain, and Leriche’s textbook, La Chirurgie de la Douleur, held Paulo’s interest. He not only performed these surgeries, he also reported the results of his experiments involving the sympathetic system.

In 1939, he joined the Souza Aguiar Municipal Hospital (formerly the Hospital de Pronto Socorro), where he directed his attention to brain injury. There, in 1945, he founded the first Department of Neurosurgery devoted to neurotrauma in Latin America, at a time when traumatic brain injury was almost exclusively managed by general surgeons. This department became a remarkable center for teaching neurotraumatology. As early as 1948, he reported the management and outcome of his first 1000 traumatic brain injury cases. In 1949, Niemeyer presented his experience with 1500 such injuries at the IVth International Congress of Neurology in Paris.

In 1942, Paulo founded the Department of Neurosurgery at the Santa Casa de Misericórdia Hospital of Rio de Janeiro. Eight years later, he also founded the Department of Neurosurgery at the Casa de Saúde Dr. Eiras in Rio de Janeiro. At this private institution, he established a multiprofessional team with the neurologists...
Abrahão Akerman and Benedito Mettre and the neurophysiologist Hélio Bello. In a few years, these 2 departments became the standard for neurosurgery in Brazil. At Santa Casa de Misericordia and Casa de Saúde Dr. Eiras, Paulo also started functional surgery and later introduced microsurgery. Important figures in the neurosciences, including Macdonald Critchley, Charles Drake, Murray Falconer, Henri Gastaut, Guy Lazorthes, Peter Janneta, Wilhelm Tön尼斯, and Earl Walker (Figure 3), came to Brazil to participate in conferences and symposia under Niemeyer’s direction.

Believing that the application of technology was crucial for neurosurgery’s advancement, Paulo performed the first electrocorticographies in Brazil and reinforced the use of electroencephalography and electrocorticography as regular diagnostic tools for tumor resections, movement disorders, and epilepsy surgeries.

Because of Brazil’s close cultural ties to Portugal, Paulo was aware of the early explorations of angiography in that country. In the late 1940s, he was one of the first to use angiography systematically as a diagnostic procedure for brain tumors and vascular lesions as he worked on establishing vascular neurosurgery in South America. In 1947, 19 years after the first cerebral angiography was performed in the Americas by Egas Moniz and Augusto Brandão Filho in Rio de Janeiro, Niemeyer introduced the technique of percutaneous cerebral angiography in Brazil.

In 1949, Niemeyer published an extensive review in Portuguese on the clinicoradiological features and surgical management of arteriovenous malformations. The review included his first 10 cases and was cited in significant international publications (Figure 4). In 1953, Paulo published a detailed article on the angiographic features of brain herniation. The next year he introduced an ingenious modification for the challenging percutaneous catheterization of the horizontal segment of the vertebral artery (V3).


Oscar Niemeyer

Oscar Niemeyer was born in Rio de Janeiro 7 years before Paulo (Figure 5). Oscar graduated from the National School of Fine Arts in Rio de Janeiro in 1934. He then joined a team of Brazilian architects collaborating with the Swiss-born French architect Le Corbusier on a new building for the Ministry of Education and Health in Rio de Janeiro. Niemeyer worked on this project with Lucio Costa and Le Corbusier until 1938. Murals of Candido Portinari rendering Brazilian economic cycles, a sculpture by cubist artist Jacques Lipchitz, and Burle Marx’s landscapes enriched the construction, which became an architectural milestone.

In the Brazil Builds exhibition at New York’s Museum of Modern Art in 1943, the architect Philip S. Goodwin stated that “Brazil has had the courage to break away from the safe and easy path with the result that Rio can boast the most beautiful government building in the Western hemisphere.” Together, Niemeyer and Costa designed the Brazilian Pavilion for the 1939 World’s Fair in New York City. Their innovative ideas ignited interest in architectural design in South America.

Awarded projects from sectors of West Berlin and suburbs of Havana to the Caracas Museum of Modern Art, Oscar’s international career quickly progressed. In 1947, the American architect Wallace Harrison invited Oscar to join a commission in charge of designing the United Nations headquarters in New York and to submit a proposal. Niemeyer’s project was selected unanimously (Figure 6A). In deference to his mentor, Le Corbusier, also a member of the architects’ commission, Oscar

FIGURE 2. Paulo Niemeyer in the early 1940s. Courtesy of Paulo Niemeyer Filho.
modified the original sketches slightly, primarily in the location of the General Assembly building and the terrain. Perhaps wishing his ideas had been accepted without change by the committee, Oscar stated: "But it doesn’t stop me from feeling a bit sad when I see the photo of the built complex. Oh...the United Nations Square that I designed is missing so much!" Nonetheless, the complex was inaugurated in 1950 with international recognition that it was Oscar Niemeyer’s conception (Figure 6B).

LANDMARKS IN FUNCTIONAL SURGERY

In the early 1940s, with an abiding interest in neurophysiology, Paulo Niemeyer started to manage movement disorders surgically, using Putnam’s pyramidotomy and cortical extirpation, as advocated by Bucy and Klemme. These destructive lesions of the pyramidal tract offered satisfactory relief of tremor but affected motor strength adversely. In 1945, Niemeyer reported positive results in 14 patients, primarily patients with Parkinson’s disease. Nine patients underwent pyramidotomy and 2 underwent cortical extirpation of Brodmann area 4. In 1 of these 2 latter cases, he identified an area that suppressed motor responses during stimulation of the premotor cortex. Tremor was thereby eliminated, and the electrical cortical activity observed on electrocorticography of area 4 was reduced significantly. He tried to demonstrate, as described in animal studies, the existence of cortical spreading depression in the human brain. Garol and Bucy first identified the suppressor strip in humans just anterior to the precentral gyrus. In 1946, Paulo published the related study of suppression of the motor response and the electrical cortical activity in humans. Penfield cited this study in his textbook *Epilepsy and Functional Anatomy of the Brain*.

In 1955, Paulo reported a larger series of patients with movement disorders with a longer follow-up. Patients with spasmodic torticollis who underwent anterior radicotomy at the cervical level and those with torsion dystonia who underwent anterior cordotomy and bilateral anterior cervical radicotomy improved. Athetotic patients did not respond to extirpation of Brodmann area 6. He also stated that parkinsonian patients could not be cured, but cortical extirpation provided more lasting tremor control than pyramidotomy. Paulo was not satisfied with his results, which confirmed those of other contemporary series. Such outcomes led Bucy to state that cortical extirpation “should not be undertaken unless the tremor is so severe that hemiparesis will be welcome in its place.” Accordingly, Paulo also stated that “it is now unacceptable for an operative technique to aim to treat a symptom—the tremor—and to cause a new illness, the hemiparesis.”

Traugott Riechert offered Niemeyer a stereotactic frame, which allowed Paulo to perform the first stereotactic surgery for Parkinson’s disease in Latin America in 1954 (Figure 7). In 1 year, he performed 16 stereotactic surgeries, including 6 pallidotomies. The management of these last 6 cases was detailed in the study entitled “Surgical Treatment for Dyskinesias” published in 1955 and later cited by Ernest Spiegel and Henry Wycis.
Throughout the 1940s and 1950s, neurosurgeons, neurologists, and neurophysiologists attempted to elucidate the pathophysiology of temporal lobe epilepsy. These years witnessed the first use of electroencephalography to localize epileptic foci, \textsuperscript{50,51} the identification of clinical epilepsy subtypes, \textsuperscript{47,52} the first epilepsy surgery based on electroencephalographic localization of pathological electrical activity, \textsuperscript{47,53,54} and explorations of electrical potentials recorded from the cortical surface that were actually arising from “underlying cortical areas, eg, the cornu ammonis” \textsuperscript{55} or “underlying rhinencephalic structures.” \textsuperscript{56,57}

In 1948, Gibbs et al\textsuperscript{58} confirmed the temporal origin of seizures in a large series of patients with psychomotor epilepsy. They stressed that the response to antiepileptic drugs was poor, which instigated the surgical management of this entity at different centers.\textsuperscript{54,59-61} These early series involved anterolateral temporal corticectomies and provided limited results; the absence of pathology of the tissue resected was frequently noted.\textsuperscript{47} Bailey et al\textsuperscript{62} stated that the chance to obtain seizure control was greater in the presence of a pathological lesion rather than based on electroencephalographic findings alone. Crucial experimental studies reproducing psychomotor seizures had unveiled the role of the mesiotemporal lobe and its association with cortical seizure activity.\textsuperscript{63-66} Niemeyer, with the help of Bello, used electrocorticography to study the epileptogenic activity of the hippocampus and detailed the correlated cortical activity.\textsuperscript{67} Importantly, Niemeyer reported a 44-year-old woman with psychomotor seizures at late follow-up after undergoing a temporal lobectomy for a posterior communicating artery aneurysm.\textsuperscript{67} Seizure control was achieved after the hippocampus and parahippocampal gyri were resected.

It was recognized that a temporal lobectomy should include the uncus, amygdala, and hippocampus. Subsequently, Penfield and Baldwin\textsuperscript{68} described their subtotal temporal lobectomy, identifying the pathological evidence (“incisural sclerosis”) in the surgical specimens and relating it to temporal lobe epilepsy. In 1956, Morris\textsuperscript{69} reported that 78% of his patients were free of psychomotor seizures using a similar technique. Citing improved outcomes, Paulo preferred en bloc resection of the temporal cortex, parahippocampal gyrus, amygdala, and hippocampus.\textsuperscript{67} Gastaut\textsuperscript{49} commented on these surgical procedures: "These findings suggest that the operation does not always remove all the structures responsible for the attacks and that in some cases it merely removes structures playing a secondary part in the course of its clinical or electroencephalographic manifestation.”

Niemeyer\textsuperscript{67} believed that psychomotor epilepsy had its origin in the “nucleus amygdalae, in the tempo-insular cortex or in the hippocampus” and these structures formed a “functional unit, responsible for the production of psychomotor attacks, leaving in the majority of cases the temporal cortex in a secondary place.” Based on his neurophysiological results, Paulo showed “astrocytic gliosis, particularly in the areas H2 and H3 of the hippocampus, which were the best studied ones, marginal and perivascular gliosis and cellular rarefaction” in his surgical specimens,\textsuperscript{70-72} which he claimed supported the probable secondary role of the temporal lobe. Based on these findings, Paulo tailored a procedure in which the amygdala and hippocampal...
Meyer explained the technique:

In a letter mailed to Gastaut, Niemeyer explained the technique:

Rio de Janeiro, November 16, 1956

My dear friend Gastaut,

I would like to ask your impression of a new operation that I have used for psychomotor epilepsy, based on your studies. For anatomic, physiologic, and experimental reasons and because the focus of this epilepsy is usually in the nucleus amygdale, in Ammon’s horn, or in the hippocampus of gyrus, I resected these 3 structures via a transventricular approach, almost without touching the temporal cortex.

During the procedure, I stimulated the hippocampus and saw that the temporal cortex appeared to be in synchrony with the hippocampal discharges, the sharp waves and spikes, almost exactly where the spontaneous focal anomalies had been, giving the impression that they were secondary.

I have called this operation a transventricular amygdalohippocampotomy, and I presented the first seven cases at the Interamerican Congress of Surgery, November 9th, in Sao Paulo. All the patients improved; two still have a few crises, but from a mental perspective the results were excellent. Two others underwent surgery too recently (30 and 15 days, without crises) to draw any conclusions. But it appears to me that after surgery, the EEG returned to normal in almost all cases.

I think that one of the advantages of this operation is that it permits more adequate resection of the hippocampus that can be obtained solely with an extensive lobectomy. The resected Ammon’s horns demonstrated the histological lesions so well discussed at the Marseilles Colloquium, especially the gliosis in areas H1, H2 and H3. The employed technique does not allow anatomic study of the nucleus amygdale and hippocampus, which are aspirated by suction.

I will present this study at the next Congress of the League, in Brussels, but I would very much like to have your critique.

Please, my friend, accept my best regards.

Best regards, Henri Gastaut

In 1957, as a special guest and the only representative of South America, Paulo participated in the Second International Colloquium on Temporal Lobe Epilepsy, sponsored by the National Institutes of Neurological Diseases and Blindness in Bethesda.73 Paulo presented the study “The Transventricular Amygdalo-Hippocampectomy in Temporal Lobe Epilepsy,” which was then published in 1958 in the book Temporal Lobe Epilepsy.67 Paulo described the approach as follows:

The transventricular amygdalo-hippocampectomy was employed only when the temporal cortex was grossly normal. A 2-cm incision was made on the second temporal gyrus, avoiding injury to cortical vessels. The temporal horn of the lateral ventricle is opened and the hippocampus exposed. After the electrographic study, the hippocampus is ablated in an extension of 3 cm, and the n. amygdalae and gyrus hippocampi are removed by subpial suction, until the basal arachnoid appears on the whole extension of the exposed ventricular floor. By transparency through the arachnoid, we can see the tenuiretum and the communicating and posterior cerebral arteries.67

In 1973, Niemeyer and Bello presented the use of microsurgical techniques to refine the operation at the Fifth International Congress of Neurological Surgery in Tokyo.74 Later, Wieser and Yasargil75 described the selective amygdalohippocampectomy using the transsylvian approach, and Olivier66,67 modified the surgery via the superior temporal sulcus.

During the 1950s, the intense interchange between Gastaut and Niemeyer through frequent visits to Rio de Janeiro and at international meetings was elemental in the development of both selective amygdalohippocampectomy and epilepsy research in Brazil.9 Gastaut addressed a series of conferences on epilepsy hosted by Niemeyer in Rio de Janeiro between 1954 and 1955. Gastaut attended the International Symposium on Electroencephalography in 1955 in Rio. The meeting was organized by Niemeyer and presided by Earl Walker, with Bartolome Fuster, Leão, Mosovich, and Villavicencio on the faculty.78 Moreover, Bello himself observed important experiments in Marseilles on electrical stimulation of the amygdala and hippocampus.79 Years later, Niemeyer and Gastaut exchanged letters on this topic, celebrating their experiments and the increased application of the selective amygdalohippocampectomy:
PIONEERING MICROSURGERY IN BRAZIL

Along with leading Brazilian neurosurgeons José Ribe Portugal and Elyceu Paglioli, Niemeyer was one of the founders of the Brazilian Society of Neurosurgery, which was organized on July 26, 1957, during the First International Congress of Neurological Surgeons in Brussels.

In 1970, Niemeyer visited the microsurgical laboratory headed by M. Gazi Yasargil at the Department of Neurosurgery at the University of Zurich. He was impressed by the advantages offered by the microscope during neurological procedures and enthusiastic about the impact of such a tool on patient outcomes. When the microscope technology could not be imported to Brazil during the military dictatorship from 1964 to 1985, Paulo cooperated with D. F. Vasconcellos S.A. from Sao Paulo to develop an operating microscope for neurosurgery. This microscope was subsequently used in the majority of neurosurgery departments in South America.

Applying the improvements offered by magnification and illumination, Niemeyer performed the first extracranial-to-intracranial arterial bypass in South America in 1971, completing a superficial temporal artery-to-middle cerebral artery anastomosis. Four years later, he reported the successful treatment of 8 patients who underwent cerebral revascularization. He handcrafted his own aneurysm clips using steel fishhooks and designed another masterpiece, the Oscar Niemeyer Museum in Curitiba, which was inaugurated in 1996, the Niterói Museum of Contemporary Art is regarded as one of his masterpieces (Figure 11G). He also conceived of the Miserico Hospital of Rio de Janeiro in 1976 (Figure 9).

LANDMARKS IN ARCHITECTURAL MODERNISM

Oscar Niemeyer was a pioneer in exploring the constructive possibilities of reinforced concrete. His buildings are composed of rectangles, semicircles, harmonic curves, ellipses, hyperbolas, and abstract forms that impart a sensation of equilibrium. The lines of his buildings are futuristic and gravity-defying. He stated the following: “If you think of the Renaissance, you think of buildings heavy on the bottom and light on top. I don’t believe in this.”

In 1956, the former Brazilian president Juscelino Kubitschek boldly planned a new capital for Brazil to move it from Rio de Janeiro to the hinterland. Niemeyer, Costa, and Marx became responsible for building this new city from scratch (Figure 10). Oscar designed the government buildings in the capital Brasília, which was founded in 1960. The National Congress, Presidential Palace, Metropolitan Cathedral of Brasilia, and the Itamaraty Palace are among his main conceptions (Figure 11). The political significance of this architectural creation on Brazil has been stunning—the development of a new region where millions of people live and one of the main tourist attractions of the country.

ENDLESS ENDEAVOR

At the 1997 World Federation of Neurosurgical Societies Meeting in Amsterdam, the Committee on the Medals of Honor nominated 5 neurosurgeons for their contributions to neurosurgery: Jules Hardy, Paulo Niemeyer, Kenichiro Sugita, Arnoud de Vet, and Mahmut Gazi Yasargil. By pioneering many techniques in South America, providing a unique neurological literature in Portuguese, and visiting or inviting...
surgeons and scientists of leading centers in different subspecialties, Dr. Niemeyer instructed numerous residents and contributed his experience to the formative years of various residents and generations of Brazilian and South American neurosurgeons, including his son, Paulo Niemeyer Filho who is an active neurosurgeon in Brazil. Paulo and his wife were known for their Saturday open houses, where guests felt at home and knowledge was discussed. These events, aside from formal scientific meetings, were important for connecting and influencing the younger generation of neurosurgeons in Brazil. Paulo worked actively at his office until he died at the age of 89 in 2003.

In 1988, Oscar was honored with the Pritzker Architecture Prize. He celebrated his 100th birthday in 2007 and is still working on several projects. The Niemeyer Cultural Center, which is being erected in Aviles, Spain, and the Oscar Niemeyer Auditorium in Ravello, Italy, constitute the 2 major projects in process. He still works everyday at his office on the top floor of a building overlooking Copacabana beach.
CONCLUSION

Although in different fields, the Niemeyer brothers had several traits in common: they were inventive, creative, and motivated, and both had an innate sense of spatial relationships. Neurosurgeons must develop an acute sense of 3-dimensional space to remain oriented when approaching surgical targets from odd, non-orthogonal angles. Architects must conceive of space in the same...
way—they must see in the mind’s eye every line, edge, curve, and dimension of a building that may only be on paper and comprehend its composition and framework as neurosurgeons must comprehend the structure of the brain. Paulo and Oscar each labored in complex spaces that they created. Although Paulo’s greatest contribution to neurosurgery may have been through the gentle curves and symmetry of the gyri, sulci, and the mesiotemporal lobe brain structures, Oscar’s contribution lies in the curves, dimensions, materials, and symmetry of some of the most impressive and pleasing architecture that the world has known (Figure 12). In many ways the Niemeyer brothers’ visions for space, volume, and dimension were similar—just in different environments—this cannot be by chance. The brothers evolved in comparable scale and their work reached international prestige. Through their explorations of sinuosity, each brother significantly influenced the world for human improvement and comfort (Figure 13).

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in the article.

Acknowledgments

We thank Dr Paulo Niemeyer Filho for providing valuable documents and photographs that greatly assisted our study. All letters reproduced here were generously provided by Paulo Niemeyer’s son, Paulo Niemeyer Filho, and were translated by the first author. Part of this study was presented at the 2009 AANS Annual Meeting in San Diego, where it was awarded First Place Scientific Eposter in the category of History.

REFERENCES


