Clinical anatomy as a modern concept for 21st century teaching, postgraduate education, and research

Bernhard Hirt, Thomas Shiozawa

Institute of Anatomy, Department of Clinical Anatomy, Eberhard Karls University, Tuebingen, Germany

Anatomy faces new challenges in the 21st century. Exponential growth of knowledge, paradigm shifts in medical education, and the scientific trend to subcellular and molecular research make an impact on the institutions of today. We described our concept of clinical anatomy as a contemporary and innovative model for student teaching, postgraduate training, and applied clinical research.

Anatomy can also foster interdisciplinary teaching along with the clinical, especially surgical, professions to give students a direct link to the application of anatomical knowledge. Furthermore, clinical students can be relegated to the conceptual framework of basic sciences during their clinical rotations.

Clinical anatomy can provide a unique platform for postgraduate training, because cadaveric human body specimens can be used as realistic and safe models for practicing even the most complex surgical procedures. Lastly, the study of clinical anatomy can facilitate applied clinical research, as new operation techniques and new devices and instruments can be tested and evaluated in a realistic setting. Therefore, this new concept of the study of clinical anatomy provides a modern, up-to-date model for teaching anatomy in this day and age.

Key words: clinical anatomy, teaching, dissection, postgraduate surgical training

Background

Anatomy is one of the oldest subjects in medicine. Although having evolved over time, the common purpose of the scientific field, over decades, and even centuries, is the explanation of the structure and morphology of the human body. Traditionally, most professional anatomists were also clinically trained; and, therefore, their research was oriented toward the human structure. However, the vast expanding knowledge in the second half of the 20th century more and more turned to sub- and ultrastructure; therefore, the applied and clinical aspects of anatomy began to fade. This resulted in the reduction of anatomical content in the curricula and the decline of clinically qualified anatomists. However, in the ’70s and ’80s of the last century the growing demand in different medical branches for detailed knowledge of specialized anatomy, e.g., the development of new technology, was recognized. This rejuvenation was attended by the foundation of the British and American Association of Clinical Anatomists, in 1977 and 1984, respectively, and also the launch of the journal.

In Germany, the discussion about anatomy, and how anatomy related to clinical medicine, peaked at that time in a well-remembered article by the anatomist Herbert Lippert about the “Dehumanisation of anatomy and medicine.” He called for a more clinical and living, teaching approach for undergraduate anatomy, resulting in a broad controversial discussion in the whole medical community.

This emphasis on clinical anatomy, against the background of the development of many different medical technologies, also brought the need for profound anatomical knowledge back on screen for science and research and, for the first time, for postgraduate, surgical, training. The first Center for Clinical Anatomy in Germany was founded by Bernhard Tillmann, in 1994, in Kiel, followed by similar institutions in Cologne, Hanover, Mainz, Muenster, Halle, and Tuebingen. To date, many anatomical institutes have hosted postgraduate training courses; however, not many devote themselves to clinical and macroscopic anatomy as a field of research.

The concept of clinical anatomy in Tuebingen was
originally proposed by Prof. Ulrich Drews, former chair of the Anatomy Department of Experimental Embryology. As the gap at the end of the last century between anatomical research and the education of medical doctors widened, Prof. Drews sought the solution in bringing the study of anatomy back to the clinical and, especially, the surgical sciences. Coincidentally, the Institute of Anatomy was planning a new building at that time, which was then constructed as a new teaching building on the clinical campus (Figure 1). The basic layout was then designed to provide a setting for teaching clinical anatomy, as well, and this was the nucleus for what the department is today.

**Concept and development in Tuebingen**

The development of the Department of Clinical Anatomy in Tuebingen started with the new teaching building. The requirement was a new facility for the dissection course and cadaver processing, the outcome was an innovative and visionary concept for teaching anatomy and clinical anatomy.

**Student teaching**

The study of medicine in Germany requires 6 years. The first 2 years mainly cover the basic sciences (anatomy, biochemistry, and physiology) leading up to the first state examination. Three clinical years are followed by a practical year, after which the second state examination concludes the medical studies.

The Medical Faculty of Tuebingen University applies this traditional 2-step curricular structure; however, the curriculum was always remodeled with small but constitutive changes. The most impacting external regulatory requirement was a new federal legislation on medical education in 2002 (Ärztliche Approbationsordnung, ÄAppO). The major alteration for the preclinical curriculum was the requirement to integrate more clinical content into the basic sciences. Therefore, in anatomy, we established a new teaching format with the *Sectio chirurgica*, an anatomically moderated, surgical prosection which is held in parallel to the dissection course. In this course the heads of the different surgical departments of the University Hospital perform characteristic and demonstrative operations on specially embalmed cadavers, moderated by an anatomist. This interdisciplinary approach helps students to see the relevance of anatomy for the surgical disciplines, and highlights the differences of the surgical and anatomical approach at the same time.

From the start, the acceptance of the medical students was very good, as it was from the advanced students in the clinical years. As their interest and the demand increased, and our lecture hall capacities reached its limits, we decided to provide the *Sectio chirurgica* from 2009 on also as an Internet-based live stream. This format proved even more successful, because students from all over Germany (and Austria and Switzerland) could subscribe and view actual surgical operations in real time. With a chat option, the Internet viewers can also take an active part by asking the surgeons questions. To date, about 20% of all medical students in Germany have registered for the *Sectio chirurgica*. The last season, with 12 operations on living patients ranged from a kidney excision and transplantation to an implantation of an artificial heart, was seen by approximately 25,000 students.

The *Sectio chirurgica* shows an excellent way to integrate clinical content into a traditional medical curriculum. The interdisciplinary approach proves very useful in producing a coherent anatomical and surgical course curriculum, supplementing the very valuable, traditional dissection course. Using modern broadcasting technology, the conspicuity and impact of anatomy on the clinical education increased enormously, even far over the borders of Tuebingen.

Furthermore, we are not only engaged in preclinical teaching. Anatomy may also play a relevant role in clinical education, especially when talking about complications of interventional procedures. In the initiation phase of the local skills lab, the department of internal medicine asked us to cooperate with them by teaching practical skills. Martin et al. reported that residents who underwent a structured, anatomy-based training on central venous line placement produce significantly fewer pneumothoraces than did their untrained colleagues. Based on these findings, we
Clinical anatomy as a modern concept

developed an anatomical training session with emphasis on the neck, regarding the catheter placement technique and possible complications. This became a required module in the internal medicine skills training, which actually takes place in the anatomical dissection hall. As a second means of educating medical students in a realistic surgical environment, we initiated a course teaching endoscopic anatomy. Students were trained to analyze anatomy via endoscopic views on cadavers. They learned to use endoscopes dynamically to search for specific structures. We recognized that this educational concept is able to longitudinally connect basic anatomical knowledge with clinical relevance.

Postgraduate training
Having started with loose cooperation with several clinical partners in the university hospital, the contribution of the Department of Clinical Anatomy to postgraduate education has also changed tremendously over the last years. The building and basic hardware proved a perfect setting for surgical training courses to many disciplines. Starting with anesthesiology and orthopaedic surgery, soon training courses in neurosurgery, ear, nose, and throat (ENT) surgery, maxillofacial surgery, gynecology, and trauma surgery followed. The present infrastructure allows us to host training courses of varying size (Figure 2). In 2012, we hosted 60 national and international training course events, training about 1,000 surgeons from 12 different disciplines.

Infrastructure
The floor plan is centered around the semicircular shaped dissection hall on the ground floor, the first floor comprises seminar rooms and a histology lecture hall. The basic hardware: operating room (OR) equipment with an OR table, operation microscope, ultrasonic device, and laparoscopy tower, was already included. Over the years, we acquired more equipment. Now we offer 11 workplaces with OR tables (Trumpf Merkur, Trumpf GmbH + Co. KG, Ditzingen, Germany), High definition (HD) laparoscopic/arthroscopic tower (Karl Storz GmbH & Co. KG, Tuttlingen, Germany), basic surgical instruments (Aesculap AG, Tuttlingen, Germany; KLS Martin Group, Tuttlingen, Germany; Karl Storz), and LED (light-emitting diodes) surgical operating lamps (KLS Martin Group). After beginning with live (real time) surgery transmissions in 2008, we established one Karl Storz OR1® master workplace (Karl Storz) for demonstrations (Figure 3). Several HD camera systems provide high quality overview and insights for telemedical purposes. In 2011, a livestream broadcast studio was added. We established technical architecture to combine the existing OR1® master workplace including the Karl Storz AIDA® (Karl Storz) documentation system with a Tricaster™ 855 live production system (NewTek Inc., San Antonio, TX, USA). Sound processing is facilitated with a Sennheiser Integrated System (Sennheiser Electronic GmbH & Co. KG, Wedemark, Germany).

Cadaver processing
For the dissection course, formalin (4%) fixation is used. For the training of surgical procedures, an alcohol-glycerol mixture, as described previously, proved very valuable. Advantages are the authentic haptics of the soft tissue, which allow full mobility of joints for arthroscopy and CO₂ insufflation of the abdomen for laparoscopy. Limitations to these fixation methods are the preservation of the brain and the relatively fast evaporation time of the fixation fluids. The latter requires a more intensive maintenance of the specimen if stored
and used over a longer period of time.

Applied anatomy research
The cooperation with various clinical disciplines and medical devices companies naturally suggests scientific cooperation. In a clinical anatomy department, the possibilities and limitations of new surgical techniques can be tested under safe conditions on the most realistic model— the human cadaveric body.

Special ties exist to the departments of neurosurgery, ENT, obstetrics and gynecology, and hand and plastic surgery. In neurosurgery, several new approaches were described, with a focus on endoscopy versus microscopy (Figure 4). The endoscopic extension of the retrosigmoid suprameatal approach optimizes the visualization of the sellar and parasellar regions. First usability testing of different new prototype endoscope systems were performed in an anatomical setting to check usability in neurosurgical standard approaches like the anterolateral or retrosigmoidal, as well as for a ventriculoscopic approach, and visualization for aneurysm surgery.

A special challenge in gynecology is pelvic floor surgery, because the numbers of patients increase rapidly and many new, mainly minimal invasive operation techniques arise. As the pelvis presents an anatomically highly complex and three-dimensionally challenging region, we evaluated several new pelvic floor repair systems. The anatomical conditions for different mesh applicators like the Gynecare TVT-O, Gynecare PROLIFT and Gynecare PROSIMA were first implanted in anatomical cadavers to evaluate the requisite surgical procedures. This was clearly foresighted because nowadays many of these products are viewed critically because of the increasing occurrences of complications.

Surgical cadavers were also used to develop new surgical measures for free flap transplantations in the field of plastic and reconstructive surgery. Moreover, with the study of clinical anatomy, we provide a platform for companies to test their newly developed implants and for surgeons to test and/or practice new surgical approaches. For example, the first retinal microchip allowing blind patients to see again was first tested for the surgical procedure and fitting of the implant on a cadaveric specimen in our facility.

Discussion
The 21st century is a great challenge for anatomy because the settings change with new educational paradigms, technological advances, and the demands of the various institutions and societies. Against this background, the need for a sound anatomical education is now more important than ever. The surgical disciplines involved have already expressed their concerns about the quality of anatomical education. In 2009, the German Society of Surgery even made "Anatomia — quo vadis?" (‘Anatomy — where to go?’) a main topic of their annual congress. There is also amounting data supporting a decline of anatomical knowledge in the recent years.

Our concept of teaching clinical anatomy tries to counteract this development, taking effect on several levels:

- The undergraduate teaching concept connects basic sciences and clinical application. With the Sectio chirurgica, we have succeeded in creating an innovative, transdisciplinary, nationwide, combined anatomical and surgical lecture course. It is clearly necessary to discuss how this approach may be transferable to other institutions. And we also clearly see a need to teach anatomy clinically applied in the preclinical phase, and then to review anatomy during clinical studies so that students remember it and we can point out its relevance, e.g., to help avoid complications.

- Anatomy can take a major part in postgraduate education, because we can exclusively provide the most realistic training model there is — the human body, with all its anatomical variants. With modified fixation procedures and sufficient OR equipment, we can offer an up-to-date surgical training environment, including audio and video technology for telemedial transmissions via the Internet accessible from anywhere in the world.

- To further support the development of medical technology and surgical science, the study of clinical anatomy can play a key role for interdisciplinary cooperation and scientific exchange, providing a platform for cutting-edge applied research. The
accelerating technological advances are also realities in medicine; and novel surgical devices, innovative procedures, and ground-breaking, new approaches provide a great opportunity for clinical anatomy to be in the vanguard of this great technological evolution.

We believe this concept to be a beacon for a 21st century study of clinical anatomy and would encourage other institutions to follow on this path. It may lead this magnificent academic field back to clinical recognition, to expedite the applied sciences, and to a better quality of medical and health care for the next generation.

References