Putting Experimental Dynamics into the Field: The German ‘Ostfeldzug’ and the Creation of Emergency Care Chains in Military Neurology and Neurological Surgery, 1941–1945

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Abstract
Background: The interconnections between the history of neurology and neurological surgery with the development of modern, technological warfare are a vastly under-researched area of medical history. The main objectives of this paper are hence to contribute to the understanding and analysis of a major case example from World War II. Materials: The article’s research is based on work at the Bundesarchiv in Koblenz, the Max Planck Gesellschaft in Berlin, and literature regarding the Fuehrungsstab der Luftwaffe, undertaken as part of a larger scale project on the history of the neurosciences and psychiatry in the first half of the 20th century. Summary: The current article focuses particularly on the Ostfeldzug of the Wehrmacht and the creation of emergency care chains in military neurology and neurological surgery. Its results show how major German neurologists, such as Otfrid Foerster, Wilhelm Toennis, Georg Merrem and Klaus Joachim Zuelch have contributed to the development of emergency care chains in military neurology. Key Messages: In conclusion, despite the atrocities and often-inhumane ways through which knowledge was gathered in contemporary military neurology, a better understanding of modern neurology can be gained from a critical assessment of the history of military neurology during World War II.

Introduction
Medical and military histories alike have long emphasized the important developments in ambulatory care for wounded soldiers from the vital threats and dangers of battlefields [1]. When looking back at the seventy-five years since the outbreak of World War II, there are particularly two areas in which a closer focus at military neurologists and neurological surgeons in the German army can be seen as fruitful, since they inaugurated an innovative concept of emergency care chains for brain-injured soldiers in military action. What is striking when taking into consideration these historical examples is the observation of how swiftly the new protagonists of military neurology and neurosurgery transitioned from medicine in civilian life to their effective adaptation for contexts of direct warfare. The emergence of a very special group of military neurologists and neurosurgeons shall be detailed in this article – a group of medical pupils who had all been trained by the eminent neurological surgeon Emil...
Heymann (1878–1936) at the Augusta hospital of Berlin [2]. Through their clinical and basic science experiences, Heymann’s trainees had become well versed in the latest neurological diagnostic approaches and neurosurgical treatments. This new group of military neurologists and neurosurgeons received their personal introduction in laboratory work and intensive research training at two central scientific institutions, which had been heavily supported by the Kaiser Wilhelm Society as well as the American Rockefeller Foundation. In the following sections, first, the biographical and training background of the young members of this group of German-speaking neurologists and neurological surgeons shall be elucidated; second, their involvement in the German war effort, particularly the four-year time period of the Ostfeldzug against Soviet Russia will be traced; finally, the argument is developed that their experimentally inspired medical and care approaches soon became the instrument of strategic economic reasoning in the military context.

The Formation of a new Scientific Expert Group

During World War II, Wilhelm Toennis (1898–1978) became the leading figure of ‘experimental neurosurgery’ in Germany – pioneering surgical techniques for tumor removal, reconstructive vascular operations on the brain and nervous system, as well as cerebrospinal fluid measurement and encephalographic diagnostic techniques [3]. The second individual was Klaus Joachim Zuelch (1910–1988) [4] and the third Georg Merrem (1908–1971) [5]. They all took some part of their practical clinical training and scientific career with Emil Heymann, who had received his education with the pioneering researcher in the area of intracranial tumor removal and pituitary gland resection (first performed in 1905), Fedor Krause (1857–1937) in Berlin [6]. Krause acted as a consulting neurological surgeon to the German army during World War I and continued his research on the long-term effects of nerve traumas, peripheral nerve sutures, and projectile removal from the brain in the early years of the Weimar Republic. Heymann later succeeded Krause in 1921 and took up his position at the Augusta hospital in Berlin. In his service at the Augusta hospital (see fig. 1), Heymann introduced many of the most recent neuroradiological approaches of the day, such as pneumoencephalography and myelography along with innovative intracranial surgical techniques to prevent hemorrhages and bleeding in traumatologic surgery and tumor oncology [7]. In 1933, however, when the National Socialists seized power in Germany; Heymann who was Jewish was expelled from his position at the Berlin teaching hospital [8].

It is crucial now to introduce the three contemporary protagonists in military neurology and neurological surgery in this article: Wilhelm Toennis was born in the industrial city of Dortmund and had been an active participant in the military medical corps during the World War I [9]. He entered the department of physiology at the University of Hamburg after the Great War in order to pursue experimental animal research, before resuming his clinical training at the surgical department of the University of Frankfurt. In August 1934, Toennis became the head of Germany’s first specialized and independent division of neurological surgery in Wuerzburg. Three years later, he moved on to Berlin where an inaugural associate professorship for neurosurgery had been established for him in conjunction with the Hansaklinik at Schumannstrasse in Berlin-Mitte. Already one year later, he assumed the additional scientific headship of the new department for tumor research and experimental neuropathology at the Kaiser-Wilhelm-Institute (KWI) for Brain Research in Berlin-Buch [10]. At the KWI, Toennis succeeded in developing Hans Berger’s (1873–1948) electroencephalograph further, bringing it from a predominantly laboratory technique to a research tool for clinical

Fig. 1. ‘Operation scenery in the Augusta hospital in Berlin during the 1930s. Carl Max Behrend (1895–1963) (second on the right) assists Emil Heymann (second on the left). Trainee Georg Merrem is a spectator (slightly upper left from Heymann’s head). In the front right corner, an electric cauterization device can be seen, which was used for neurological surgery and cauterization of small blood vessels.’ The photograph was taken ca. 1934 (the image is part of the public domain). Collmann H, Rosenow DE, ‘Fast Vergessen: Emil Heymann – ein Pionier der Neurochirurgie in Deutschland,’ Schriftenreihe der Deutschen Gesellschaft fuer Geschichte der Nervenheilkunde. 2008, p 410.
applications [11]. Toennis’ revised neurograph thereby opened many new practical dimensions of dynamic experimental research for both animal and human investigations in this cutting-edge brain research laboratory at the KWI [12]. From the neurophysiological animal studies of his research group, Toennis inferred that the time window to treat acute brain injuries was comparatively small, so that neurologists and neurological surgeons in trauma care needed to act very quickly if they were not to lose their patients from prolonged transport times or later during the operations [13].

The second protagonist from the group of military neurologists and neurological surgeons was Georg Merrem, who was born in Koenigsberg in East Prussia on September 21, 1908; and he studied medicine between 1927 and 1929 at the University of Tuebingen. Merrem’s later scientific dissertation at the University of Berlin was published in 1933 as ‘The Treatment of Multiple Sclerosis (MS) with Germanin’ [14]. Until the year 1938, Merrem continued to hold the official position of a staff attending physician in the Berlin Augusta hospital under Emil Heymann and through the guidance of the latter’s pupil, Martin Behrend (b. 1878), who specialized in research on early rehabilitation of neurological and neurosurgical patients [15].

Finally, the third member of the innovative group of contemporary military neurologists and neurosurgeons who had trained and worked together in Berlin, Klaus Joachim Zuelch, shall be introduced. He was born in Allenstein in East Prussia in 1910 as the son of a family of theologians and educators, his father serving as mayor of the city of Allenstein between 1910 and 1932 [4]. After his medical studies at the Universities of Marburg, Rostock, Vienna, Berlin and Heidelberg, Klaus Joachim Zuelch graduated with his M.D. in 1935. During his residency in Otfrid Foerster’s (1873–1941) neurological service at the University of Breslau as well as the Prussian military center of Potsdam, he became deeply involved in the most advanced neurosurgical techniques for the treatment of brain cancer and cerebral scars after injuries along with the conservation of cortical brain functioning [16]. Also, the acquaintance in Breslau with Percival Bailey (1892–1973) – the Chicago-based protagonist of American neurosurgery – influenced Zuelch’s decision to dedicate his own career to neurological surgery. One year before the outbreak of World War II, he joined Toennis at Berlin’s Augusta hospital, where he completed his neurosurgical training, and in his research activities he particularly collaborated with Toennis on questions of cerebral neurography aligned with clinical and laboratory-based electroencephalographic studies [17].

The Group of Military Neurologists and Neurological Surgeons during the 1940s

It is crucial to take the institutional role of Berlin’s Augusta hospital into account as it emerged as the cradle of contemporary military neurology and neurological surgery [18]. Here, the group of medical protagonists of the new field established enduring social and friendship bonds, while continuing important collaborative scientific programs especially directed at trauma surgery, the development of cauterization knives to reduce brain hemorrhage, or the use of neurography for the prediction of neurorehabilitative and neurosurgical outcomes. Then came the German attack on Poland on September 1, 1939 and, first, Wilhelm Toennis was called to duty on the Eastern Front. In fact, his own contribution to the German war effort went far beyond the normal range of a medical doctor, as he rapidly pursued an exceptional career even within the German military system. Over the years, Toennis enjoyed many promotions to become a chief staff surgeon (Leitender Sanitaetsinspektor) – in the rank of a major (Brigadegeneral) of the German air force [19]. He had been so fully accepted and his expertise valued that he was even able to convince his superiors in the German Luftwaffe of the pressing necessity of a rapid surgical treatment of brain-injured soldiers, when demonstrating to them his experimental findings from the preceding research work with Berger’s neurograph at the KWI [20]. Among the many other impulses that Toennis gave for military medical developments was the initiation of the first airborne patient transports of severely head- and brain-injured soldiers. They were brought from the direct frontlines to specialized military hospitals in Posen, Breslau as well as the Prussian military center of Potsdam. As a responsible officer for organizing the innovative airborne ambulance units, Toennis actively recruited Merrem from Berlin to act as an accompanying flight physician with the task of educating and training further military surgeons in the required medical and surgical tasks ‘in the air’ as it were [21].

Toennis’ notorious rescue units became responsible for the primary treatment of the severely injured, particularly after the attack on Soviet Russia began on June 22, 1941 [22]. Toennis’ organizational program developed into a very effective medical operation, which is highlighted through the list of his ‘special patients’ on whom he, as the leading expert, had operated. These included, for example, the general of the air force Kurt Student (1890–1978); Albert Kesselring (1884–1965), another general of the air force; General Field Marshall of the air.
force, Dr.-Ing. Wolfram Freiherr von Richthofen (1895–1945), who had been active with the 8th air corps on all fronts in Europe (who later died from a cerebral tumor); and General Lieutenant Walther von Huenersdorff (1898–1943). Despite the successful neurosurgical operations on the first three above-mentioned army leaders, von Huenersdorff’s operation subsequent to airborne transport behind the lines – an elective operation at the neurosurgical department in Posen, where access was chosen through the frontal bone of the skull in order to retrieve the bullet particles in Huenersdorff’s frontal cerebral lobes – unfortunately failed and the patient could not be rescued, since his injuries by a precision sniper bullet were too severe [23].

A very important stepping stone for the neurosurgical rescue operations was Toennis’ explicit appointment as the advisory specialist for brain surgery with the medical director through the Chief Command of the Luftwaffe [24]. Toennis’ ‘qualified emergency air transport’ (qualifizierter sanitätsdienstlicher Lufttransport) largely concentrated on the most severely wounded, especially those suffering injuries of the cranium, brain, the eyes, and the jaw (bone) due to bullet wounds, grenade splinters, and abrasive explosion results [25]. With respect to the scope of the emergency airborne units, they came to include three Junkers Ju 52 transport airplanes, in which twelve patients on stretchers and a number of sitting patients could be transported. In addition, two small Fieseler Fi 156 stork (Storch) reconnaissance airplanes served as ‘loader planes’ from or nearby the battlefields (see fig. 2); they could carry only one or two patients on stretchers [26]. The airborne emergency units in the German army further included ground ambulances and the technical and healthcare personnel needed for the operation and maintenance of such vehicles. Altogether eleven such airborne emergency units served on the Eastern Front. An astounding number of approximately 2.5 million casualties were transported between 1941 and 1945 by these specialized airborne emergency units along with regular troop carriers [27]. Another military neurologist of the former Berlin group was highly instrumental in the creation of innovative first-aid units on the ground and even in overt combat situations: Klaus Joachim Zuelch, accompanied the 5th tank regiment of the 3rd tank division on the Eastern Front [28]. He had come up with the original concept of using the shelter and armored security of the highly mobile tanks to enable physicians and surgeons to move out to the battlefields themselves and rescue the wounded soldiers even from most dangerous frontline situations. For this emergency medical aim, Zuelch used specifically designed ambulance tanks (Sanitätspanzer) that could carry three stretchers and were further equipped with surgical instruments, emergency drugs, fixation devices, and dressing materials. They were manned with a physician or surgeon, often with an assisting nurse [29]. Within the network of Toennis’ wider airborne emergency rescue system, Zuelch’s ambulance tanks carried injured soldiers back to the first-aid casualty stations, from where they were transported by the Fieseler storks and JU52 airplanes to the above-mentioned specialized hospitals behind the frontlines [30]. As a military physician, Zuelch took part in three major operations – against Poland, France, and later Russia – his most extensive service being with the Wehrmacht on the Eastern Front in the struggle with the Soviet Union. There he worked in four of the military hospitals set up in congruence with Toennis’ airborne emergency and rescue system. Zuelch held directing positions in these hospitals and became strategically involved in the transformation of the mobile supply chains in the tank corps of the German army.

During the offensive against Poland between September 1 and October 6, 1939, the overall number of ca. 50,000 total casualties was comparatively low for the German army. Zuelch only had to treat superficial head and flesh wounds, yet was not directly engaged in any active combat situation despite how he had planned his
Emergency Care Chains in Military Neurology and Neurological Surgery

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Between Frontline Care and Hospital-Based Training

After a long vacation in Austria and a period of work in the military service of the Augusta hospital in Berlin from 1940 to 1941, Zuelch was again one of the first medical specialists to accompany the tank divisions near Brest-Litovsk as they became mobilized in the Spring of 1941, in preparation for the commencement of Operation Barbarossa, June 22, 1941 [32]. Zuelch often engaged in medical rescue actions at the immediate frontline, treating the severely wounded and accompanying them back to more central and secure care stations. In pursuing these medical rescue operations, he also needed to get out of the protective armor of the tanks to provide bandages, assess the severity of the medical injuries – following a triage-oriented grading scheme that singled out life-threatening general organ and brain injuries, along with burns (particularly in tank personnel), then skeletal and skull fractures (which impeded ground and airborne transport), severe localized or multiple injuries, allowing for ambulatory transportation, and finally lighter injuries, which could be treated through first aid on the spot (e.g., fracture reposition, ligation of bleeding arteries and wound dressing, as well as the suturing of superficial skin wounds). In the late fall of 1941, Zuelch happened to become a victim of a sniper bullet himself, which severely injured his left elbow [33]. Through sheer coincidence with the service timetable, Toennis was on call at the military hospital in Posen when Zuelch arrived, and he became Zuelch’s operating surgeon. Toennis’ greeting to his former pupil was tongue in cheek while evincing great concern: ‘Oh, Zuelch, this is you. I thought you would be bringing us some brain injured soldiers!’ [28]. Following the operation and another half year of stationary clinical work at Berlin’s Augusta hospital, Zuelch eventually returned to his unit in 1942 near Charkow in the Ukraine and took part in the ensuing offensive toward the Volga and the Caucasus. Throughout the summer, Zuelch continued endeavoring to rescue injured combatants near the Don River, in the course of which a gun hit his ambulance tank and he received wounds from grenade splinters in both his legs. He was transported from hospital to hospital, until he eventually arrived back at the Augusta, where his colleague Toennis operated on him again [34]. As historically bizarre as the sequence of events might appear, it in fact occurred as a result of Zuelch’s pre-planned concept of an emergency rescue chain to free himself from the role of being the director of a military hospital or chief of a neurosurgical ward. He held the conviction that such a position should be taken by the most senior military neurologists as they were perceived to be less physically able, so that fitter individuals like him could cope with the demanding duties of the rescue operations [34]. Following the successful treatment of his own injuries, and two months of recreation on the Baltic Sea, Zuelch returned to his tank unit, which by then had driven deep South into the Caucasus to engage in fierce battles with retreating Russian troops. Here again, Zuelch was wounded in his left elbow and had to be transported back to the Breslau Neurological Institute where Victor von Weizsaecker (1886–1957) now became his physician.

After a three-month convalescence period, Zuelch took on the directorship of a hospital near Branitz in occupied Czechoslovakia, where he basically organized a military neurology unit modelled after the former organization of the neurosurgical department at the Augusta hospital in Berlin (see fig. 1) [35]. At Branitz, he occupied himself with mastering suboccipital brain puncture techniques, and more than one thousand pneumoencephalographies were conducted by him and his collaborators to allow for early neurosurgical treatment options [36]. Furthermore, Zuelch established a successful rehabilitation group led by injured physicians and nurses, who were not physically fit to return to the front but who could make a marked difference to the functioning of the clinical and research services at Branitz. Hence, the lightly wounded cared for the severely wounded, which presents us today with an absurd picture of the war effort at this point, though the German practice was undoubtedly efficient. Following its evacuation to Dresden, in 1945, Zuelch’s military hospital became officially dissolved and he moved on to Hamburg. The director of the clinical department of neurology – Heinrich Pette (1884–1967), another former pupil of Wilhelm Toennis – offered him a
clinical position in his neurological service, shortly before British troops arrived in the northern harbor city [37]. In order to better situate Zuelch’s medical and administrative place in the group of military neurologists and neurological surgeons under consideration, it is important to compare it with Wilhelm Toennis and Georg Merrem, the two other protagonists of this group. Apart from his major organizing role in the ambulatory and hospital system for the German military, Toennis continued to actively serve as a neurosurgeon in the Hansaklinik and the Augusta hospital in Berlin throughout the war [38]. In 1939, he simultaneously directed the Hôpital Français in occupied Brussels, but fully returned to Berlin in 1941 where he became responsible for setting up and running the major rehabilitation barracks complex on the Reichs Olympic field and stadium in Charlottenburg. According to Toennis’ own descriptions, which he submitted in a report to the German Military High Command for decision-making purposes, he thoroughly estimated that altogether three percent of all severely injured soldiers had been transported by his airborne evacuation system and that he and his Berlin group alone had treated ten percent of all the brain-injured soldiers in the German army [39]. Georg Merrem, conversely, remained mostly within local hospital services and did not move out to the front as much [5]. Yet the continuity of his work with the military hospitals in Berlin enabled Merrem to assume a major role as the background educator for a new generation of emerging neurologists and neurological surgeons. After he had trained sufficient neurosurgical care units for the airborne transport system, Merrem himself became a director of military hospitals in Berlin, Breslau, and in Dresden. He worked at the central end of the medical supply chain and gained vast experience in intracranial operations, especially regarding the cerebrospinal fluid system, and neurographical diagnostic applications [40].

**Conclusion**

Although the overarching concept of the military neurology and neurosurgical air evacuation system presents itself as a very rational rescue and care idea, a major planning impetus came from the physicians’ affiliation with local army divisions. It also emerged from earlier neurophysiological considerations that Toennis, Zuelch, and Merrem had made in the course of their pre-war collaborations, supported by the Kaiser-Wilhelm Society. This means that the idea of neurosurgical rescue and care chains grew largely out of contingent factors, while their placement in the German army and air force served these military neurologists and neurological surgeons as well as a ‘field of prolonged medical experimentation’, which depended on personal contact networks and the direct supervision of Toennis for the set-up of the care chain system – not to mention his own surgical care for his former pupils when they were wounded. The major rationale for the creation of a tank- and plane-based system of neurosurgical care stemmed from the increasing demands for speedy rehabilitation and reuse of highly specialized, resource-intensive personnel [41] – for example, pilots, officers, and physicians – an idea which has become embedded in the triage hierarchy of military neurology ever since.

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