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COVER EDITORIAL

Typical brachial plexus: the legacy of a forgotten anatomist, Abram T. Kerr (1873–1938)

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Abstract
The brachial plexus, a complex network of nerves responsible for innervating the upper limb, exhibits remarkable anatomical variations. This editorial explores the composite drawing of a "typical" brachial plexus portrayed by Abram T. Kerr in 1918. This composite drawing of the typical brachial plexus stands as a critical contribution to the field of anatomy and surgery, and encapsulates the most prevalent patterns of formation, branching, and origins within the brachial plexus, offering a statistical map of its common variants. Kerr portrays the typical brachial plexus as a foundational resource for anatomists and medical professionals seeking to navigate the intricate landscape of this neural structure. It serves as a hypothetical model, reflecting the common arrangement of trunks, cords, and branches, shedding light on the typical composition of the plexus observed in most individuals. Beyond being a visual representation, the 'typical' brachial plexus provides a bridge between theoretical knowledge and practical applications, aiding in the identification of variations and deviations in surgical contexts. This composite drawing enhances our comprehension of the intricate and ever-evolving anatomy of the brachial plexus, reinforcing its role as a fundamental reference point for anatomical studies and clinical practice.

Keywords Anatomy · Brachial plexus · Nervous System

Background

The brachial plexus exhibits significant anatomical variations among individuals. Studies report variations in up to 90% of brachial plexuses, underscoring the importance of understanding and recognizing these variations for surgeons and anatomists [1, 2] (Fig. 1 and cover). Textbook descriptions and images found in anatomical and surgical atlases are often based on traditional sources and may not account for common variants, defined here as those with over 50% prevalence, of the individual elements of the plexus. Consequently, establishing a "standard" brachial plexus presents a challenge, particularly when considering the intricate arrangement of the plexus and its collateral branches.

In the early twentieth century, Abram T. Kerr (1873–1938), an anatomist based in Ithaca, recognized this challenge and envisioned creating a "typical" brachial plexus that would provide a data-driven map depicting a brachial plexus containing the commonly observed variants of trunks, divisions, cords, and branches [3]. While it does not aim to represent the most frequently encountered brachial plexus in its entirety across specimens, Kerr's typical brachial plexus serves as a foundation for understanding the nuanced anatomy of the brachial plexus. It provides a map for anatomists and surgeons, aiding in the identification of uncommon forms and variants when comparing the observed arrangement to Kerr's typical brachial plexus.

We propose the utilization of Kerr's composite drawing of the "typical" brachial plexus as the foremost representation. Kerr painstakingly sketched this composite drawing, a result of his extensive experience gained through numerous cadaver dissections, to encapsulate what he believed to be the most indicative and well-rounded version of the brachial plexus in humans. This composite drawing is the prime reference for understanding the brachial plexus, offering an invaluable resource for anatomists and surgeons seeking to comprehend the nuanced variations within this complex

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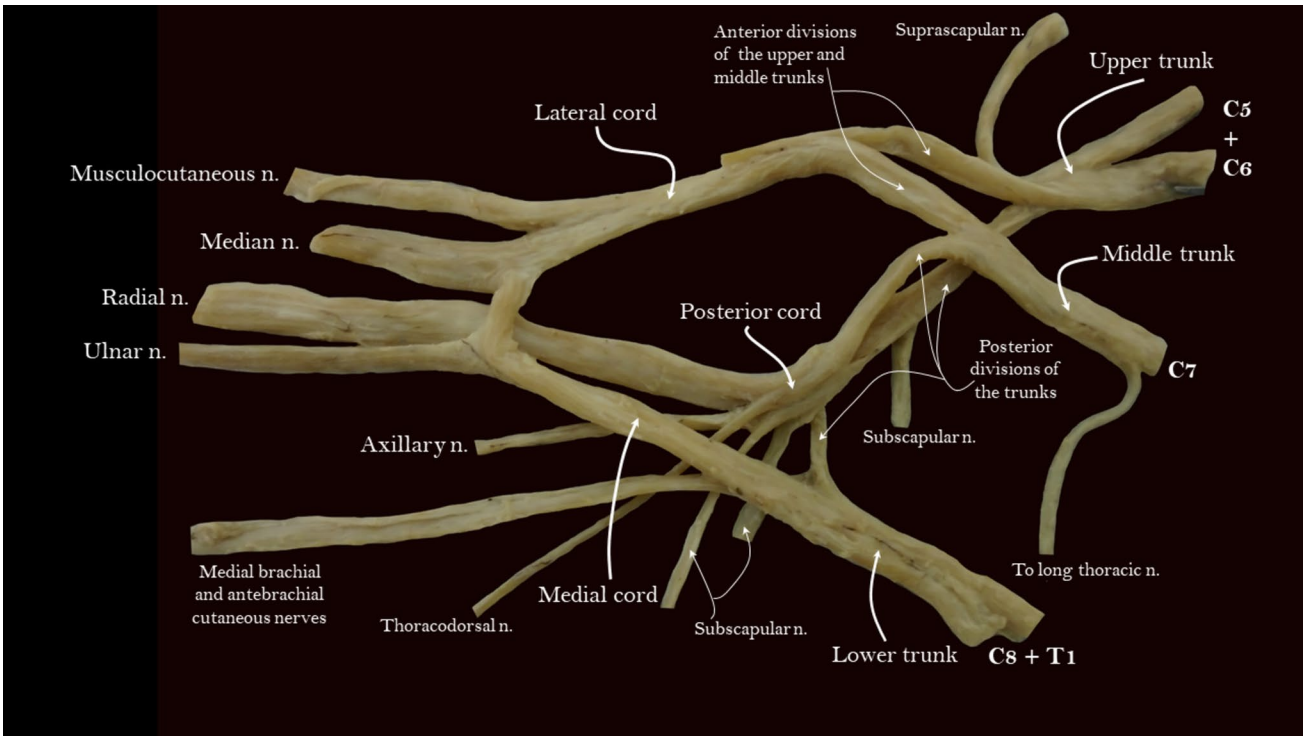

Fig. 1 and cover An ex situ human brachial plexus, right side. Note the variations in the origin of branches compared to the classic textbook version

neural structure [2]. This editorial offers a biographical account of Dr. Abram T. Kerr, followed by a detailed exposition of his typical brachial plexus, and culminating with a brief overview of the variations of the brachial plexus.

Biography

Abram Tucker Kerr (Fig. 2) was born in Buffalo, NY, on January 7, 1873. After completing his undergraduate degree at Cornell University in 1895, he returned to Buffalo to pursue a medical education, earning his medical degree from the University of Buffalo in 1897. During his medical studies, he also served as a teaching assistant for histology and pathology courses at the university. Between 1898 and 1900, Kerr held the position of adjunct professor in anatomy at the University of Buffalo. His pursuit of anatomical knowledge took him to Europe in early 1899, where he engaged in the study of anatomy in Scotland, England, and Germany. In Germany, he had the privilege of studying under Merkel at Göttingen. His overseas studies were interrupted by the untimely death of his father. Nevertheless, upon his return to the USA, he conducted anatomical research at Johns Hopkins University under the mentorship of Franklin Mall for a brief period [2].

In 1900, Kerr assumed the role of assistant professor of anatomy at Cornell University. His dedication to the field led to his promotion to a full professorship in 1904. In 1902, Kerr took on the administrative role for the Ithaca Division of the Medical College, a position he held for 36 years until the division's closure. During this time, he volunteered his services during the typhoid epidemic of 1903 and the influenza epidemic of 1918. Kerr exhibited a deep commitment to addressing health issues in Ithaca and, from 1911 to 1912, served as the president of the board of trustees of the Ithaca Memorial Hospital, later assuming the role of vice-president for several terms.

Tragically, Abram Tucker Kerr passed away on August 15, 1938, just 2 months after the closure of the Ithaca branch of the Cornell Medical School. Some believe that the school's closure contributed to his unfortunate demise, as it deeply disappointed him [2]. Throughout his scientific career, Kerr conducted significant anatomical studies. Among his notable contributions is his often-overlooked article on the variations of the brachial plexus and its branches. This treatise remains highly valuable for anatomists and physicians. To our knowledge, no other extensive work with such meticulous detail regarding this collection of nerves in the upper limb exists. The senior author has made a revised edition of Kerr's monumental work available [2].

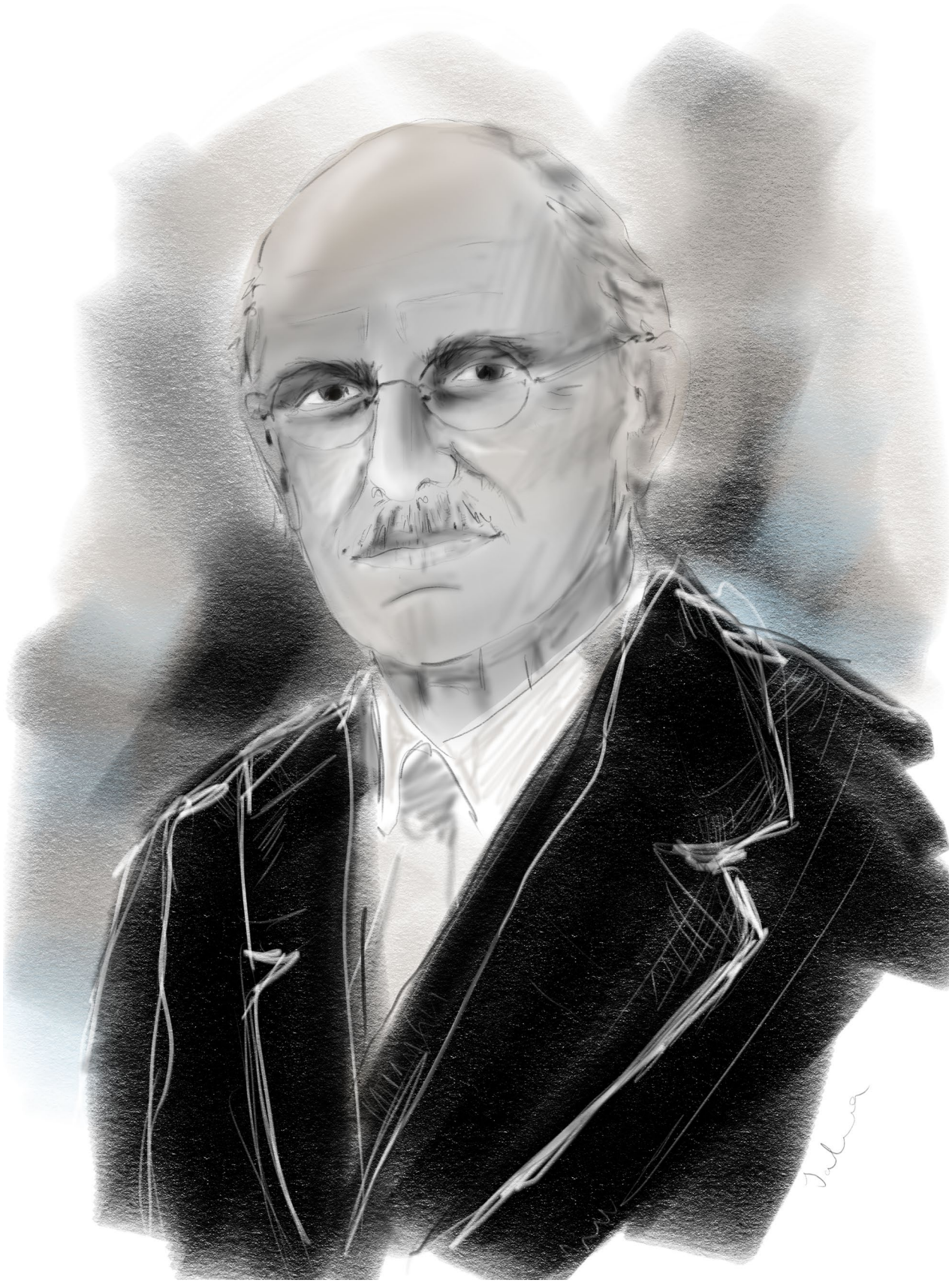

Fig. 2 Abram T. Kerr (1873–1938). A sketch portrait by Salva Shoja

Formation and branching pattern of the typical brachial plexus

Kerr's "typical" plexus (Fig. 3) serves as a statistical representation of the brachial plexus and should be regarded solely as a hypothetical model for illustrating the prevalent variants of the elements within the brachial plexus as a whole. Kerr's study relied on records of dissections conducted at the Anatomical Laboratory of the Johns Hopkins Medical School between 1895 and 1900, as well as dissections at the Anatomical Laboratory of the Cornell University Medical College, Ithaca, performed intermittently from 1900 to 1910 [3]. The formation and branching pattern of a typical plexus are as follows:

1. The upper trunk typically forms from the union of C5 and C6 (in 90% of plexuses). C4 contributes a branch to the plexus (in 63% of plexuses), with C4 joining C5 before the union with C6.

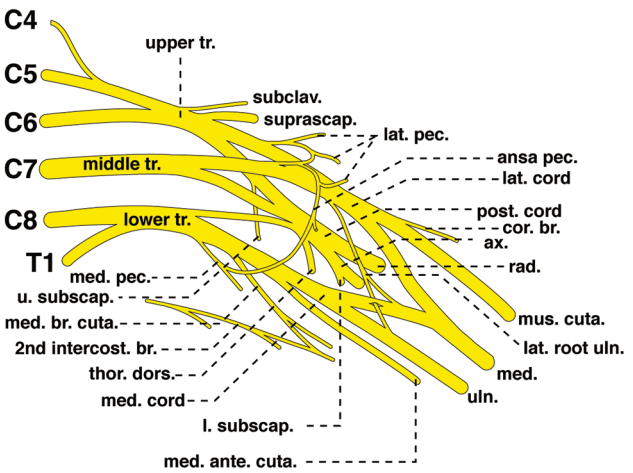

Fig. 3 A composite drawing of a "typical" brachial plexus. Adapted from Kerr [3] and reproduced with permission from Shoja et al. [2]. Note the posterior divisions of the upper and middle trunks join to form a proximal posterior cord, which is joined a little distally by the posterior division of the lower trunk to form the posterior cord. The nerve to the subclavius muscle arises from the upper trunk just at the point where C5 and C6 unite. The lateral pectoral nerve arises by two roots, one from the anterior division of the upper trunk and one from the anterior division of the middle trunk. The lateral root of the ulnar nerve arises from the lateral cord and divides into two branches, one passes to the medial root of the median nerve and the other pierces the medial root of the median nerve en route to the ulnar nerve. The upper subscapular nerve arises solely from the posterior division of the upper trunk. The thoracodorsal nerve arises from the posterior cord. The lower subscapular nerve arises as a single branch from the axillary nerve. The medial pectoral nerve arises from the medial cord. There is a communicating loop (ansa pectoralis) between the medial pectoral nerve and the inferior root of the lateral pectoral nerve. The medial brachial cutaneous and medial antebrachial cutaneous nerves arise separately from the medial cord, and the medial brachial cutaneous nerve anastomoses with the intercostobrachial nerve.

2. The middle trunk is consistently formed by C7 alone. It divides into posterior and anterior branches (in 94% of plexuses). The anterior branch typically joins the anterior branch from the upper trunk to form the lateral cord. The posterior division joins the posterior divisions of the proximal and lower trunks, or the nerves forming them, to establish the posterior cord.
3. The lower trunk is predominantly formed by the union of C8 and T1 (in 95% of plexuses). The lower trunk typically divides into posterior and anterior divisions.
4. The union of the anterior branches of the upper and middle trunks typically forms the lateral cord (in 80% of the plexuses).
5. The medial cord is primarily formed by the anterior branch of the lower trunk (in 95% of plexuses).
6. The union of the posterior divisions of the proximal, middle, and lower trunks typically forms the posterior cord (in 80% of plexuses). In nearly half of the plexuses, the posterior branches of the upper and middle trunks join to form a proximal posterior cord, with the posterior branch of the lower trunk joining somewhat more distally.
7. The ulnar nerve typically forms from the division of the medial cord of the plexus into the ulnar nerve and the medial root of the median nerve (in 97% of plexuses).
8. A lateral root of the ulnar nerve is present in nearly half of the plexuses, originating from the lateral cord of the plexus. This lateral root divides, sending one branch to the medial root of the median nerve and another to the ulnar nerve. The lateral root of the ulnar nerve pierces the medial root of the median nerve en route.
9. The musculocutaneous nerve typically arises from the division of the lateral cord of the plexus into the lateral root of the median nerve and the musculocutaneous nerve (in 88% of plexuses).
10. The median nerve typically forms through the union of two roots: a lateral root from the lateral cord of the plexus and a medial root from the medial cord (in 86% of plexuses).
11. The radial nerve typically arises as one of the two terminal divisions of the posterior cord of the plexus (in 79% of plexuses).
12. The axillary nerve usually arises as one of the two terminal divisions of the posterior cord of the plexus (in 80% of plexuses).
13. The nerve to the coracobrachialis muscle is a single branch in 55% of the plexuses, typically arising from the musculocutaneous nerve in 50% of the plexuses.
14. The suprascapular nerve typically arises from the upper trunk of the plexus (in 62% of plexuses).
15. The nerve to subclavius usually arises from the upper trunk of the plexus (in 65% of plexuses), often as a single branch.

Fig. 4 Complex interconnections and intertwining of brachial plexus funiculi revealed after removal of the epineurium through maceration Adapted from Kerr [3] and reproduced with permission from Shoja et al. [2]

16. In many plexuses, there is a communicating loop (ansa pectoralis) between the medial pectoral nerve and one of the roots of the lateral pectoral nerve.

Major variations in the composition of the brachial plexus

Kerr extended his examination of the brachial plexuses by subjecting them to maceration in an aqueous solution containing nitric acid and glycerin [3]. This meticulous procedure effectively removed the epineurium, thereby enabling a detailed examination of the principal funiculi constituting the plexus. The outcomes of this process were remarkable, unveiling the intricate and sophisticated nature of the bundle network within the plexus (Fig. 4). Drawing from data obtained through the gross dissection of over 170 brachial plexuses, Kerr categorized these plexuses into three primary groups, further dividing them into seven distinct types (Table 1). Group 1, referred to as proximal plexuses, included those in which a branch from C4 merged with the brachial plexus. In contrast, group 3 plexuses, designated as

Table 1 Subdivisions of the brachial plexus

Group	Type	Lateral cord composition	Medial cord composition	Anatomical features
1	**A**	C4–C7	C7–T1	The C4 sends a branch to the brachial plexus; there is a connecting branch from the middle trunk to the medial cord
	B	C4–C7	C8–T1	The C4 sends a branch to the brachial plexus; there is no connecting branch from the middle trunk to the medial cord or from the lower trunk to the C7 or the lateral cord
	C	C4–T1	C8–T1	The C4 sends a branch to the brachial plexus; there is a connecting branch from the lower trunk to the C7 or the lateral cord
2	**D**	C5–C7	C7–T1	The C4 does not send a branch to the brachial plexus; there is a connecting branch from the middle trunk to the medial cord
	E	C5–C7	C8–T1	The C4 does not send a branch to the brachial plexus; there is no connecting branch from the middle trunk to the medial cord or from the lower trunk to the C7 or the lateral cord
3	**F**	C5–C7	C8–T1	The C5 sends a branch to the cervical plexus; there is no connecting branch from the middle trunk to the medial cord or from the lower trunk to the C7 or the lateral cord
	G	C5–T1	C8–T1	The C5 sends a branch to the cervical plexus; there is a connecting branch from the lower trunk to the lateral cord

distal plexuses, featured C5 sending a branch to the cervical plexus. Plexuses categorized as group 2, identified as intermediate plexuses, were characterized by C5 neither receiving a branch from C4 nor giving off a branch to the cervical plexus [2].

Conclusion

A comprehensive knowledge of the brachial plexus aids in planning surgical approaches, identifying potential nerve injuries, and preserving the integrity of vital neural structures. The "typical" brachial plexus, as depicted in Kerr's composite drawing, serves as a graphical representation to illustrate the typical patterns in the formation and branching of the brachial plexus and is a unique representation of this complex neural structure. Rather than aiming to capture a single, specific instance of the brachial plexus, Kerr's drawing is a statistical amalgamation of the common forms observed in numerous specimens. It offers a visual summary of the conventional arrangement and branching patterns found within the brachial plexus. This composite drawing is a valuable educational tool for anatomists and medical practitioners. It provides a baseline understanding of the brachial plexus by highlighting the prevalent nerve connections and division patterns. While individual plexuses may exhibit variations, Kerr's composite drawing offers a reliable reference point for comprehending the fundamental architecture of this intricate network of nerves. In essence, this drawing allows anatomists and surgeons to grasp the commonly encountered form of the brachial plexus, aiding in identifying recurring variations and facilitating a deeper understanding of this critical neural structure. It is a vital resource that helps bridge the gap between theoretical knowledge and the intricate reality of human anatomy, deepening our understanding of human anatomy and enhancing the quality of patient care by promoting accurate diagnoses and successful surgical interventions.

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Author contribution The conception of this article was by MMS. Drafting of the manuscript was carried out by TT, AP, SL, GBS, and MMS. The final manuscript was reviewed and approved by all authors.

Availability of data and materials Not applicable.

Declarations

Ethical approval Not applicable.

Conflict of interest The authors declare no competing interests.

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