Morphological Variations in Brachial Plexus of Beagle Dogs: Evaluation of Utility as Sources of Allogeneic Nerve Grafts

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ABSTRACT. Basic studies were carried out to apply frozen allogeneic nerve grafts in dogs after wide-ranging defects of the brachial plexus due to surgical resection of tumor. In this study, morphological variations in branching patterns of the brachial plexus were examined in ten beagle dogs, to evaluate whether the brachial plexus might represent a useful source of allogeneic nerve grafts. Spatial relationships between the axillary lymph node, which had the possibility of carcinomatous metastasis, and the musculocutaneous (MC) nerve, which was important for the function of the forelimbs, were also investigated. In all ten cases examined, the brachial plexus received ventral roots from the fifth cervical nerve to the first thoracic nerve. No significant variation in the branching pattern was found in any nerve except the phrenic, MC and dorsal thoracic nerves. Four communicating branches were observed and had some morphological variations which might be negligible for nerve grafting. Considering previous physiological and anatomical reports, the most important nerve to be reunited in graft operations for functional recovery is the radial nerve. The MC nerve and median or ulnar nerve should also be considered as possibilities for reuniting. Distances between the axillary lymph nodes and the MC nerve ranged from 11.2 mm to 21 mm (mean ± SD: 16.1 ± 2.3 mm). In conclusion, it was suggested that morphological variations in the brachial plexus were technically acceptable to apply allogeneic nerve grafts at least in beagle dogs.

KEY WORDS: axillary lymph node, beagle dog, brachial plexus, branching pattern, variation.

MATERIALS AND METHODS

This study was approved by the Animal Research Committee of Iwate University. Twenty brachial plexuses were obtained from ten healthy beagle dogs after euthanasia with sodium pentobarbital (75 mg/kg i.v.). The cervical part and forelimbs were fixed with 10% formalin, and stored in 50% ethanol.

After removal of the skin, the superficial pectoral muscle was transected from the origin on the surface of the sternum and separated from the deep pectoral muscle. The superfi-
cial pectoral muscle was then incised from the proximal half
of the humeral insertion. The deep pectoral muscle was
transected from the attachments to the sternum and
humerus. Both muscles were displaced, exposing the bra-
chial plexus. Connective tissues around the plexus were
carefully removed, and the nerves, muscles, blood vessels
and lymph nodes were identified.
Ten forelimbs were examined anatomically and branch-
ing patterns of the brachial plexus were recorded as line
drawings and photographs. In the other ten forelimbs, the
distance between the ALN and MC nerve was measured
with a slide caliper.

RESULTS

Macroscopic observations: After dissection, nerve fibers
were clearly identified as white fascicular structures.
Branching patterns of the brachial plexus were easily recog-
nized macroscopically (Fig. 1) and recorded as line draw-
ings (Fig. 2), but nerve fibers less than 0.5 mm thick were
omitted from drawings, as they were too small to follow
macroscopically.

Spinal root origins of the brachial plexus: In all ten
cases, the brachial plexus comprised ventral roots from the
fifth cervical nerve (C5) to the first thoracic nerve. Details
are shown in Fig. 3. In addition, 5 of 10 cases received
extremely thin fibers (< 1 mm thick) from the second tho-
racic nerve. These fine nerve fibers are not included in Fig.
3.

Branching-patterns of the brachial plexus: No signifi-
cant variations in the branching pattern were found in the
following 8 nerves: suprascapular (f in Fig. 2), subscapular
(g in Fig. 2), radial (Rd; B in Fig. 2), axillary (i in Fig. 2),
median (Md; C in Fig. 2), cranial pectoral (h in Fig. 2), cau-
dal pectoral (CaP; j in Fig. 2) and ulnar (Ul; D in Fig. 2)
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The phrenic (n in Fig. 2) nerve received fibers from C5
and the sixth cervical nerve in 3 cases, and from C5, the
sixth cervical nerve and seventh cervical nerve in 7 cases.

Four types of communicating branches were found,
namely Co1, Co2, Co3 and Co4 (Fig. 2). Through Co1, the
cranial pectoral nerve (h) communicated with: the CaP
nerve (j) (5 cases); the eighth cervical nerve root (3 cases);
or both the CaP nerve (j) and the eighth cervical nerve root
(2 cases). Through Co2, the MC nerve (A) communicated
with: the proximal common trunk (PCT) of the Md and Ul
nerves (C and D) (2 cases); CaP nerve (j) (2 cases); or both
the PCT (C and D) and CaP nerve (j) (6 cases). Through
Co3, the Rd nerve (B) communicated with the dorsal tho-
racic nerve (m in Fig. 2) in 9 of the 10 cases. Co4 displayed
communication between the MC (A) and the Md nerve (C)
in 9 cases. Branching patterns are summarized in Fig. 4.
VARIATION IN THE BRACHIAL PLEXUS OF THE DOG

In summary, variability of branching patterns was predominantly determined by the existence of communicating branches Co1-Co4.

Distance between ALN and MC nerve: In all 20 cases, ALN were located on the branch of the lateral thoracic nerve to the cutaneous trunci muscle. Distribution of distances between ALN and MC nerve is shown in Fig. 5. Distances ranged from 11.2 mm to 20 mm (mean ± SD: 16.1 ± 2.3 mm). In 11 of the 20 cases, accessory ALNs were observed caudal to the ALN, on the same branch of the lateral thoracic nerve.

DISCUSSION

The present study is the first morphological report which demonstrate no significant variation in branching patterns of brachial plexus based on precise anatomical analysis between the same breed, beagle dogs. These results coincide with the pattern of the MC, Md, Rd and Ul reported in previous studies on the brachial plexus of dogs [1, 10].

Data from the present study indicate that morphological variations in branching pattern of the brachial plexus between donor and recipient are negligible. Worthman [21] studied the functional innervation of the main nerves to the forelimb by transecting each nerve in dogs. In cases of Rd nerve transection, all joints other than the shoulder remained flexed, and weight-bearing on the leg was not possible due to paralysis of the triceps brachii muscle. For MC nerve, dogs displayed some difficulty elevating the paw to the edge of a table, due to paralysis of the special flexors of the elbow. With Md and/or Ul nerve transection, no lameness was evident other than slight sinking of the corpus and fetlock due to loss of tone in the flexors of these joints.

Taking account of these results in addition to general anatomical knowledge [4, 9], the most important nerve to be reunited in a surgical graft operation for functional recovery is the Rd nerve. MC, Md and Ul nerves should also be considered for reuniting where possible.

In Fig. 6, we perform morphological simulation of an allogeneic nerve graft when the ALN becomes too large to secure forelimb function. In the simulation, when the area marked with an asterisk between the two vertical lines is removed in resection of the tumor, the brachial plexus displays a wide-ranging defect of nerve continuity. As little variation in the spinal root origins of nerves forming the brachial plexus were observed, these nerves it might be possible to reunite these nerves with an allogeneic nerve graft, even if different branching patterns of the brachial plexus are present.

In clinical situations, PCT will necessarily be removed during resection of a tumor in cases of the ALN with cancer metastasis, whereas Rd and MC nerves might be spared, depending on the size of the ALN. Measurements of the distance between the ALN and MC nerve indicate that when the ALN is larger than about 16 mm in diameter, tissues involving PCT, Rd and MC nerves are likely to be removed.

In conclusion, it was suggested that morphological variations in the brachial plexus were technically acceptable when applying allogeneic nerve grafts, at least in beagle dogs.
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REFERENCES

Fig. 4. Summary of branching patterns in brachial plexus. No (or negligible) variation was found in dark-stained nerves, including B, C and D. Obvious variations were evident in clear nerves, including A. All symbols are the same as in Fig. 2. ■: Nerves displaying no (or negligible) variation.

Fig. 5. Distribution of distances between the axillary lymph node and the musculocutaneous nerve. Circles indicate individual cases (n=20).

Fig. 6. Morphological simulation of allogeneic nerve graft. ■: Simulated allogeneic nerve grafts. All symbols are the same as in Fig. 4.


