Functional Distribution of Arteries Supplying the Dog Mandible

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It has been often experienced that the infusion material in an artery flows into the neighbouring capillaries belonging to the other arteries which were previously ligated. To clarify the possibility of such a stream, the present experimental study was attempted. This stream may be performed through the capillaries or arterio-arterial anastomoses, and caused by the muscular pressure in the neighbouring tissue or of the vascular wall, which pushes the infused material to noninfused vessels. Function of the arterio-arterial anastomosis has been already discussed but that of the capillary has not been perfectly done. When the intestinal arteries were infused, the infusion material can be transported to the neighbouring capillaries by the intestinal peristaltics. From these results, the possibility of blood flow to the ischemic area by way of the capillaries or arterio-arterial anastomoses can be clinically predicted, and therefore in this report the function of these path ways will be described. Of course the infusion grade in the vascular trees will be different individually and infusion technics may affect the results. However, the constant results from various experiments were obtained and those results will be presented in this report.

The experimental study on the ligature of artery has been presented by many researchers, but none of the mandibular region. Tsutomi (63) reported the microangiogram in the experimental ligature of the unilateral or bilateral common carotid artery and most of the other reports on the arterial ligature of the head region described the cerebral circulation.

Materials and Methods

Forty adult dogs weighing 3 to 7 kg were prepared for this study and they were anesthetized by the Ravonal (Tiopentalnatrium 500 mg in 20 ml H₂O per kg) and the aimed artery for the experiment was exposed and ligated. The inferior alveolar artery was exposed by opening the mandibular canal at the plane through the second molar tooth indicated by letter X in Fig. 1. After ligature of one or a few arteries, the proximal part of the arterial tree or the left ventricle were opened for the canulation.

The infusion material was 10% gelatine solution added with india ink and warmed at 35°C to be kept in appropriate temperature and viscosity. The exposed arteries were the unilateral or bilateral inferior alveolar, lingual, facial, maxillary, external carotid and common carotid arteries. The arteries supplying the dog mandible are the inferior alveolar and facial arteries, and the maxillary, external carotid and common carotid arteries were chosen as their stem and the lingual artery was also chosen as the neighbouring artery.
Two kinds of the way of material, movement from the aimed artery to the neighbouring vessels, or from the neighbouring vessels to the aimed artery, can be thought. The infusion pressure will be also an important factor and therefore the unilateral experimented mandible was compared with the nonexperimented contralateral mandible as a rule. In addition, effect of the infusion pressure could be excluded by the selective injection together with the bloodstream into the artery, and the blood stream is not interrupted, in this case.

After the infusion, part of the ligature was ascertained whether or not the material passed through it, and then decapitation and fixation were carried out. Decalcification was slightly performed to avoid outflow of the material. The decalcified mandible as cut into 5 blocks as shown in Fig. 1 and the posterior cutting surfaces of the anterior four blocks were observed under a low power binocular microscope and drawn in Figs. 2 to 13. The grade of infusion were expressed with dot.

Results

The ligature of artery interrupts the infusion material, but the neighbouring and contralateral arteries may be able to infuse the supplying area of the ligated artery. Combination of the ligature can be classified into several cases but the most simple ligature is of a single artery. Next to it is ligature of several arteries. From these various combinations, the interesting cases will be described.

1. A control normal case of the infused mandible.

Fig. 2 shows right and left mandibles infused through the left ventricle. The mandibular canals are intensely infused but the osseous tissues show some difference; the periosteal and the endostea layers are of lower density than central layer, the medial parts are darker than the lateral parts, in the anterior block.

2. Ligature of the unilateral single artery.

a) Ligature of the right inferior alveolar artery (Fig. 3): The right inferior alveolar artery was ligated at letter X in Fig. 1 and the mandibles were infused through the left ventricle. In general, the left mandible was infused slightly denser, especially the anterior blocks show denser areas than the posterior blocks in the experimented mandible. In cutting surface A, there is no difference between both of the mandible but B shows some difference between them. Medial part of the experimented mandible is denser than the lateral part and the central dark line can not be recognized clearly. Cutting surfaces C and D show a little dense spots in the lateral marginal zone which are supplied by the facial artery. Dense infusion in the anterior blocks are due to the contralateral inferior alveolar artery and may also be
due to the bilateral lingual and facial arteries.

b) Ligature of the right maxillary artery (Fig. 4): The proximal stem of the inferior alveolar artery was ligated, and the maxillary artery shows almost the same results as the previous experiment but its infusion grade is relatively low. The medial part of the experimented mandible is denser than the lateral part in block B. From these two experiments, the possibility of infusion passing through the muscular

![Diagram](image-url)

**Fig. 2.** Infused bilateral mandibulae is a control case.

**Fig. 3.** A ligature of the right inferior alveolar artery.
branches of the maxillary artery will be recognized.

c) Ligature of the right lingual artery (Fig. 5): In the text book of dog anatomy by Miller et al (69), the lingual artery dose not supply the mandible but this experiment showed some difference between both of the mandible. The right mandibule shows a little difference in comparison with the left nonexperimented mandible but the infusion grade is, in general, little difference. The anterior blocks, especially cutting
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Surface A shows larger difference between both mandibles than the posterior blocks and this difference is more marked in the medial parts. This may show that the lingual artery supplies the anterior part of the mandible, especially its medial part. Effect of the lingual artery is shown with lower density of the nonexperimented medial part in cutting surface B.

d) Ligature of the right facial artery (Fig. 6): Miller et al ('69) described that

![Diagram of mandible sections showing effects of arterial ligature](image-url)

Fig. 6. A ligature of the right facial artery.

Fig. 7. Ligature of the right inferior alveolar and lingual arteries.
the facial artery sent the sublingual artery to the medial surface of the mandible. In this experiment, the endosteal layer is darker than the periosteal layer and the central dark line is not more conspicuous than the left nonexperimented mandible, but the cutting surface D shows the central dark line. Therefore, the facial artery supplies the medial and lateral surfaces of the mandible. The cutting surface A does not show these differences because of the infusion by way of the lingual artery.

Fig. 8. Ligature of the right maxillary and lingual arteries.

Fig. 9. Ligature of the right maxillary and facial arteries.
3. Plural ligature of unilateral arteries.

Arteries supplying the mandible are the inferior alveolar, facial and lingual arteries and therefore two of these arteries should be ligated.

a) Ligature of the right inferior alveolar and lingual arteries (Fig. 7) : In comparison with the normal case in Fig. 1, the left nonexperimented mandible was infused slightly low and the right mandible shows lower density than the left mandible in

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Fig. 10. A ligature of the right common carotid artery.

Fig. 11. Ligature of the bilateral inferior alveolar arteries.
general. Cutting surfaces A and B were slightly infused but C and D were rudimentally infused, especially their medial and lateral parts, although there were no central dark lines. This may show the effect of the facial artery and the contralateral lingual and inferior alveolar arteries.

b) Ligature of the right maxillary and lingual arteries (Fig. 8): This experiment was planned for exception of effect of the muscular branches of the maxillary artery

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**Fig. 12.** A selective injection into the right lingual artery.

**Fig. 13.** A selective injection into the right facial artery.
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and the lingual artery. In cutting surfaces C and D, there are some dark spots in the lateral and medial parts, and in cutting surfaces A and B, the medial parts show relatively low density than the left mandible. It may show effect of the homolateral facial artery and the contralateral inferior alveolar and lingual arteries.

c) Lingature of the right maxillary and facial arteries (Fig. 9) : As shown in Fig. 9, there is no difference between both mandibles in cutting surface A, but C and D show generally much difference. Medial part of the mandible, however, shows a little infusion grade which may be due to the lingual artery.

d) Lingature of the right common carotid artery (Fig. 10) : This experiment means the ligature of three arteries supplying the mandible but the other arterial branches supplying the neighbouring tissue are also ligated. The right mandible, in general, was little infused. The cutting surface A dose not show marked difference, and C and D show a little infusion only in the medial and lateral parts of the mandible. However, B shows the relative dense areas in the medial part of the experimented mandible. From their arterial supply, the infused area in the experimented mandible may be due to the contralateral common carotid artery. The external carotid artery resulted in the same infusion grade as this experiment.

4. Ligature of both inferior alveolar arteries (Fig. 11)

The effect of the contralateral arteries became clear to some extent and therefore this bilateral ligature was prepared. In this case, the rudimental infusion was recognized especially in the cutting surfaces A and B. From these results, it is clear that the lingual, facial and maxillary arteries affect the mandibular arterial supply. The infusion in the mandibular canal should be noticed. This may come from the lingual and facial arteries or muscular branches of the other arteries passing through capillaries in the osseous tissue.

5. Selective infusion into the artery.

a) The selective infusion into the right lingual artery (Fig. 12) : Without interruption the blood stream, the selective infusion with a small needle was carried out. Fig. 12 shows a little infusion grade in the experimented mandible but also the contralateral one shows slightly infused area in its medial part, especially in the cutting surfaces A and B. However, cutting surfaces C and D show also a little infusion in their medial parts of the mandible not only in the experimented mandible but also in the contralateral one. It may be understood here that the lingual artery sends its blood to the medial part of the mandible and also sends to the contralateral one through the well-developed anastomoses.

b) The selective infusion into the right facial artery (Fig. 13) : The medial part, especially, of the anterior blocks are more infused than the lateral part of the experimented mandible even though the infusion is rudimental in both mandibles. The contralateral mandible shows a little infusion in the anterior blocks, especially their medial part, that is, the experimented mandible shows a little infusion corresponding
to areas where the facial artery supplies, but the contralateral mandible was slightly infused only at the medial part in its anterior blocks. From these results, the facial artery is also able to send its blood not only to the experimented mandible but also to the contralateral mandible.

Discussion

1. Infusion: The infusion material was 10% gelatine solution added with India ink which has been usual technic for the study of vascular supply, and its viscosity is almost the same as the blood in mammalia according to Arima (55) and temperature of the dog is about 35°C. Effect of the infusion material to the vascular wall was avoided as much as possible. The infusion technic is said to be too difficult to obtain a constant result, but the author made efforts to obtain rather constant results.

For obtaining invariable results, the infusion was performed under maintainance of the constant infusion grade, changing the infusion pressure and speed. Since volume of the infusion material is in correlation to the results, the infusion grade in the contralateral nonexperimented mandibular region was served as an indicator of the infusion quantity and the appropriate cases obtained by this measurement were chosen from many experiments.

2. The functional arterial supply: Tsutomi (63) reported the daily results of the microgram after unilateral or bilateral ligation of the common carotid artery and he observed change of the auricle, facial skin, iris, lingua, palatine mucous membrane and brain. He noticed that there were many communications between various arteries, and frequency of new growth of the vessels as the effect of the ligature become smaller with day by day.

According to Miller et al, the principal arteries supplying the mandible is the inferior alveolar artery and the sublingual artery sprouting from the facial artery and the facial artery, but this experiment showed a role of the lingual and other arteries including their contralateral ones. In a case of ligation of the inferior alveolar artery, the infusion material reached the premolar tooth region of the contralateral mandible, passing through the intermandibular anastomosis in the mandibular symphysis. The ligature of the unilateral maxillary artery showed almost the same results as in the case of ligature of the inferior alveolar artery, but relatively low density of the infusion grade in that case showed the effect of the muscular branches. The ligature of the lingual and facial arteries resulted in a little lower density in the medial and lateral parts of the experimented mandible. The facial artery which supplies the lateral and medial surfaces of the mandible showed a little lower density in periosteal layer of both surfaces and only the medial periosteal layer showed lower density in the case of the ligature of the lingual artery. Lower density of the periosteal layers in these cases may show a possibility of arterial supply of the facial and lingual arteries. From these results, the effect of ligature of the two kinds of arteries or of the common carotid artery could be expected.
The contradictory experiments against the ligature were performed, that is to say, the selective infusion and these experiments needed only small volume of the infusion material in comparison with capacity of the vessels and therefore the infusion grade was lower, but the infused area was rather wide spread. From the same reason, the infusion was intensively darker when it was infused through the left ventricle than through the unilateral arteries.

3. The approach to clinical field: In the applied anatomy, these results could be suggestive, and the ligature of artery makes some of blood come from neighbouring arteries, as the ligature of the inferior alveolar artery which can be compensated by the facial and lingual arteries and the muscular branches of the maxillary artery. In a case of fracture of the mandible, the new-growth of vessels sprouting from the inferior alveolar artery can be expected, but the compensation by the other arteries should be made primarily until this new-growth of the vessels will be accomplished.

Summary
Forty adult dogs were prepared for this experiment. They were ansethetized by Ravonal and infused with 10% gelatine solution with addition of india ink through the left ventricle or proximal stem of the ligated artery. After decapitation, fixation and decalcification, both of the mandibles were cut into 5 blocks and the posterior cutting surfaces of anterior 4 blocks were observed under a binocular microscope. The obtained results are as the following:

1. The ligature of the unilateral inferior alveolar artery showed in the distal part than the ligated point that the more posterior part of the experimented mandible has the lower infusion grade, but the anterior part was compensated by the contralateral artery.
2. The ligature of the unilateral lingual and facial artery showed a little low infusion grade in the periosteal layer.
3. The ligature of the maxillary artery shows much lower density than that of the inferior alveolar artery.
4. The ligature of the common carotid artery resulted in summation of plural ligatures of its branches.
5. The ligature of two kinds of unilateral arteries showed less tensely infused areas corresponding to their supplying areas.
6. The selective infusion resulted in the lower grade of infusion but the spreading area was wider than the arterial supply.
7. From these experiments, functional compensation areas of the arteries were wider than anticipation from the morphological distribution.

References
(2) Ljubomudroff, A. P.: Ueber die Entwicklung der kollateralen Bahnen nach
犬の下顎動脈の機能的分布について

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1. 一侧の下顎横動脈の結紮では、それより末梢の下顎横動脈の結紮よりも低い注入度を示した。
2. 一侧の下顎横動脈の結紮では、下顎の骨膜層に近い部分で、やや低い注入度であった。
3. 頚動脈の結紮は、それより末梢の下顎横動脈の結紮よりも低い注入度を示した。
4. 総頸動脈の結紮は、その枝の結紮の総和に等しい成績を示した。
5. 一侧の動脈の2本を同時に複合結紮した場合には、単独結紮に比較して、より低い注入度となった。
6. 特定の血管への注入は、最も低い注入度であったが、その血管の形態学上の拡がりはやや広く注入された。
7. これらの実験から、動脈の機能的拡がりは形態学的拡がりよりも広いこと、即ちこれらの血管の強い代償能が証明された。