A COMPARATIVE ANALYSIS OF THE ASPIRATING CAPABILITIES OF THREE COMMON GAUGES OF DISPOSABLE DENTAL ANESTHETIC NEEDLES

By

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ABSTRACT

The literature reviewed is related to complications secondary to the administration of dental anesthetics and the armamentarium and physiology for the administration of dental local anesthetics.

A laboratory study aspirating whole anticoagulated blood in comparative tests of the aspirating capabilities of 25, 27, and 30 gauge needles is described. A cursory examination of breakage potential of the needles is described. The results are reported and discussed.

The following conclusions are made:

1. In vivo aspiration of blood is possible with 25, 27, and 30 gauge needles.
2. The larger, shorter needles aspirate slower than the smaller, longer needles with the differences being statistically significant.
3. Fracture of disposable local anesthetic needles requires multiple repetitious bending.

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INTRODUCTION

The infrequency of hematomas subsequent to dental injections tends to foster a sense of security that such an incident will not occur. Yet, few dental practitioners, following a posterior superior alveolar injection, have not had the experience of having a patient develop a suborbital hematoma. Block injections into highly vascularized areas, such as the pterygoid plexus, are hazardous. A life threatening consequence may follow if the patient has an allergic or toxic reaction to the deposition of the anesthetic solution into a blood vessel.

The incidence of vascular penetrations is such that routine endeavors at aspiration are a recommended precaution in block anesthesia. The aspirating syringe used in dentistry provides a mechanism for creating a negative pressure which will allow aspiration of human blood into the glass anesthetic carpule.

Attempts at aspiration without visualization of blood does not assure one that a vessel has not been entered. Numerous factors may interact to determine whether or not blood will be visible following aspiration. One factor is the effect of needle gauge on the ability to withdraw blood. Diameter of the needle has been said to be so critical that, within the diameter range used for local anesthetics, needles 25 gauge or larger are said to be essential to locating within a vessel by aspiration.

Three criteria have been used for evaluating differences in gauges of anesthetic needles. The primary criterion has been differences in aspiration of blood upon encounter of a vessel in vivo. Blood samples treated with anticoagulants have been used for in vitro testing of this criteria. The two other criteria important in selection of needles for local anesthetics are resistance to breakage and resistance to deflection.

This study was undertaken to demonstrate differences in functional characteristics of 25, 27, and 30 gauge needles commonly used in dentistry. Differences in the resistance of these needles to breakage was also superficially evaluated.

REVIEW OF THE LITERATURE

The report in the dental literature concerning the consequence of intravascular injections of dental anesthetic are replete. Barbour and Tovell, in 1948, declared the maximum safe rate of intravenous administration of procaine to be 1,000cc/per hour of 0.1 percent solution.[1] Calculating from this recommendation, Harris has stated that a 2.0 percent solution of procaine injected intravascularily as slowly as 2 cc. per minute would be two and one-half times faster than the maximum safe rate of Barbour and Tovell.[2]

Thirteen authors have reported or discussed factors leading to or the effects from intravascular injection of local anesthetic solutions.[2-14] Harris stated that more than one hundred deaths are reported secondary to local anesthetic administration.[2] Three of the authors have speculated that many reported allergic reactions may in fact be the result of toxic overdose.[8,11,12]

A predisposing factor to toxic reaction is the entrance into the vascular system during injection. In vivo studies have shown the overall incidence of vascular ingress to be approximately 3.2 percent of all dental injections.[3] The most frequently involved injection site has been shown to be the inferior alveolar or mandibular block with reported incidences of positive aspiration ranging from 3.6 percent to 11 percent.[2,3]

The interior diameter of the needle has been the main variable noted to alter the aspirating efficiency of the injection system.[4,11,12,15-20] The preponderance of concern over this factor is based on Poiseuilles Law.[21]

This principle expresses the relationship of factors governing the laminar flow of viscous fluids through capillary tubes with rigid walls, for example, blood flow through anesthetic needles during aspiration.[15]

The expression of Poiseuilles Law is as follows:

$$\text{Rate of Flow} = \frac{P_1 - P_2}{8L} \times \frac{\pi R^4}{\eta}$$

Where:

$P_1 - P_2$ = The negative pressure or the difference in pressure from one end of the capillary tube to the other.

L = the length of the capillary tube

η = the viscosity of the viscous fluid

π = 3.14

R^4 = The radius of the capillary tube to the fourth power

The rate of flow, being so dependent on the radius to the fourth power, has had great influence on the attention of clinicians interested in aspiration problems.[15] Great emphasis has been directed to needle gauge in delineating factors which effect aspirating efficiency.[15,19,20]

Monheims recommendation that, to aspirate, needles must be no smaller than 25 gauge and in some instances 23 gauge has been consistently quoted in the literature.[11,12,14,15,17] The recommendations, however, are based partially of results from an unpublished study of in vivo aspiration tests showing two percent positive aspiration with 29 gauge needles.[4]

In vivo and in vitro studies have shown that one can obtain 100 percent positive aspiration with needles as small as 27 and 30 gauge.[15,19,20] Black, in an in vivo study on the incidence of positive aspiration during dental injections, found no significant difference between 25 and 27 gauge needles.[20]

Forest has advocated the usage of needles no smaller than 25 gauge because narrower gauge needles may be blocked by blood constituents.[16] The range in diameter of human red blood cells is 6.75 microns to 8.5 microns.[22] The interior diameter of the 30 gauge needles used for dental local anesthesia is 15 to 20 times the diameter of red blood cells, Table I. It has been shown that red blood cells in vivo can deform to pass through cappillaries as small as 3 microns.[22]

Although four to five hundred times less abundant than the red blood cells, the white blood cells must be considered.[23] The largest white blood cells are the monocytes whose diameter range from 16 to 22 microns.[22] The amount of freeway space available, even with 30 gauge needles is one hundred microns, Table I.

Other factors effect changes in the blood viscosity and hence, rate of flow. The volume of the cellular constituents of whole blood is the major element effecting changes in blood viscosity.[24] Cellular volumes rarely increase significantly. Rises in the number of white blood cells do occur during severe illness but these occasional increases have minimal effect on blood viscosity.[24] It would seem unlikely that one would encounter a patient with a significantly more viscous blood than is normal because of increased cellular elements. In in vitro testing, blood has been shown to maintain a constant viscosity for at least

24 hours provided a suitable anticoagulant is used.[15,25,26] The anticoagulant disodium ethylenediamine tetraacetic acid (Na EDTA) removes serum calcium essential to coagulation and does not effect blood viscosity in concentration up to 1.5 mg. per milliliter.[25]

Kaznelson and Lewin Epstein theorized that false negative aspirations occur when the needle lumen is within a vessel but facing the endothelium. When negative pressure is applied the endothelium is drawn against the needle lumen and occludes it thereby preventing blood from entering into the needle. In clinical tests, involving 1649 injections, approximately one third of positive aspirations gave false negatives if the aspiration was done without rotating the needle while aspirating to avoid endothelial blockage.[27] Smith proposed, without in vivo testing, that smaller lumen needles might effect such blockage more readily.[19]

Watson theorized that the anatomy of blood vessels may have some effect on the incidence of penetration. Resilient, loosely bound arteries would be less susceptible to needle penetration than veins. Vein laceration by injection needles may also result in extravasation that could give positive aspiration without the needle being within the vessel.[28] Veins seem to be prone to extravasation following puncture according to Westwater.[29] Nazif recommended the use of finer gauge needles in patients with hemophelia to avoid vascular laceration.[30]

Reports of needle breakage are very sparse.[31,32,33,24] Wittrock and Fisher stated that, because of the infrequency of breakage, 30 gauge needles should not present too great a risk.[15]

As of 1967, The Council on Dental Therapuetics of the American

Dental Association recommended that a needle of no smaller than 25 gauge be used for dental injections.[35]

MATERIALS

The needles were obtained from two manufacturers.* The gauges and lengths of the needles used were 30 gauge short, 27 gauge short, 27 gauge long, 25 gauge short, and 25 gauge long. Ten needles from each manufacturer and each of the five gauge-length sizes were used for a total sample size of 100 needles.

Three single harpoon aspirating syringes** fitted with 2 ml. carpules of Xylocaine 2 percent, 1/100,000 epinephrine** were alternately attached by the harpoon shaft to the lever arm of the aspiration device shown in photo I. The body of the syringe was secured by a standard pipet clamp attached to the central aspirating unit.

The lever arm was centrally mounted on a threaded rotating shaft to accomplish vertical movement. Bilateral columns guided the lever arm movement and served to eliminate all but vertical motions.

Rate of aspiration was controlled by use of a gear drive to the vertical shaft powered by a 1/15th horsepower electric motor. A rheostat control was fixed at a speed of 0.0094 centimeters per second. The gear ratio was such that an initial acceleration did not occur when the drive motor was activated. The drive motor was connected in parallel with a one-tenth second lab timer. Activation was accomplished by using a thumb controlled toggle switch.

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*Sherwood Medical Industries, Inc, Monoject Division, 1837 Olive Street, St. Louis, Missouri, 63101; Mizzy, Inc., Clifton Forge, Virginia, 24422.
**Astra Pharmaceutical Products, Inc, Worchester, Massachusetts, 01606.

The blood samples were obtained from a healthy adult male. Five milliliter Vacutainers*** containing 6.0 mg. Na EDTA were used for the samples.

A 37 degree centigrade circulating water bath was used to keep the vacutainers at a constant temperature. Viscosity testing was done on an Ostwald viscosimeter at 37 degrees centigrade. Barometric pressure was noted on an aneroid barometer. Vacutainers were vented by inserting an 18 gauge needle thru the stopper before and after testing to maintain barometric equillibrium.

METHODS

Blood samples were obtained through a 22 gauge multi-sampler needle into the five milliliter vacutainers containing EDTA by vena-puncture without the use of a tourniquet. Hematocrit was 49 percent. Normal hematocrit values are 47 $\pm$ 7 percent.[24]

The viscosimetric determinations, on the Ostwald viscosimeter, involved calculations of capillary flow principles of Poiseuilles law.[37] The viscosity of blood is estimated relative to that of water. The viscosity of water is first determined to ascertain the individual viscosimeter constant. The viscosimeter constant and the mean (292.00 Sec..S.D.4.63 sec.) of five determinations of rate of blood flow through the capillary viscosimeter allows determination of the relative viscosity of a blood sample. The density of blood, 1.058 gm/ml at 37 degrees centigrade,[38] is multiplied by the viscosimeter constant, 1.1282×10^{-2}, and the rate of the sample blood flow, 292.00 seconds. The resultant value for the viscosity of the blood used for the aspiration tests in this study was 3.485 centipoise.

Following viscosity determinations the blood samples were taken and directly placed in the water bath until needed for the aspiration tests.

The procedure for each of the one hundred individual aspiration tests was as follows. A 2 ml. carpule of anesthetic was placed in a syringe. A needle was selected at random, from a blind box containing the entire sample, and attached to the syringe. Approximately one half of the solution was manually expelled from the carpule into a waste container. The thumb ring was removed from the syringe and the syringe was attached to the lever arm of the aspirating device by a threaded bracket. The syringe body was then rigidly fixed to eliminate movement.

The blood samples were agitated to thoroughly assure consistent viscosity throughout the sample. The blood sample and the water bath were elevated on a tripod until the needle tip penetrated the vacutainer top and entered approximately five millimeters into the blood sample, photo I.

The timer and gear drive mechanism were then activated by the thumb switch. The end of the needle within the carpule was observed against a light pink background for the first sign of blood entering the carpule. The thumb switch was then immediately disengaged and the time recorded to the nearest 0.05 second on the data sheet. In pretrial testing, the variation in reaction time was established statistically to be ± 0.05 seconds. The background color was selected to simulate oral mucosa.

The syringe was disassembled for the next test. The blood sample was thoroughly vented to re-establish pressure equillibrium within the vacutainer and the sample was again agitated. Used needles were placed in individual envelopes. The aspiration time was recorded on the envelope for later verification with the data sheet. The barometric pressure, noted each half hour during the testing period, ranged from 76.6-76.8 millimeters of mercury.

Data were compiled and verified for the test runs with the one hundred needle samples. A multiple regression analysis of variance was used to test the effect of the needle radius and length between gauges and within a given gauge (manufacturer variability) on the ultimate rate of flow.

A regular analysis of variance was computed to evaluate the trend of the rate of flow with respect to needle gauge and length. With this trend delineated, from the fastest to the slowest flow rate, Tukey's tests were performed to determine the level of significant difference between the gauge-length groups.

In addition to the primary study, a gross evaluation of breakage resistance of the needles was conducted. Each needle was repeatedly bent from its' vertical position on the hub to the horizontal and back to vertical until breakage occured. The number of bends necessary to fracture each needle was noted and the number of degrees of lateral excursion necessary to attain fracture were tabulated by multiplying the number of bends by ninety degrees. For each manufacturer-gauge-length group the mean and standard deviation were calculated. No further statistical evaluation was completed on this data.

RESULTS

Interactions of several factors thought to effect the rate of flow were confirmed with a multiple regression analysis. Needle gauge and length were the primary variables interacting to effect the rate of flow. Differences between the needles of the two manufacturers were not significant in rate of flow for given gauge length sizes. All other second order interactions were also nonsignificant.

Flow rates were faster in the long needles of each gauge (27, 25) than in their short counterparts.

Flow rates were faster in the smaller gauge needles than in the larger gauge needles. The 27 gauge long had the fastest rate of flow at 0.990 centimeters per second and the 25 gauge short had the slowest flow rate at 0.608 centimeters per second, chart I.

The regular analysis of variance delineated the trend expressed in chart I for the five groups as manufacturer variation was found to be non-significant by the multiple regression analysis. Tukey's tests were applied to the five groups to delineate the significance of their differing.

At the 95 percent level of confidence, the 25 gauge short differed significantly from the other four needle groups. The four needle groups (27 gauge long, 30 gauge short, 27 gauge short, and 25 gauge long) did not differ significantly from each other.

At the 99 percent level of confidence, the 25 gauge short differed significantly from the 30 gauge and the 27 gauge long but not from the 27 gauge short or the 25 gauge long.

The breakage tests revealed that a good deal of bending is needed to fracture the disposable needles irregardless of gauge. The 25 gauge short of manufacturer number one had the least articulation needed for breakage. In two out of ten cases the needles broke at 180 degrees, but the mean for the group of ten was 297 degrees. The highest mean degrees of articulation was 477 degrees for the 25 gauge short of the second manufacturer. Table II illustrates the results of the bending tests.

DISCUSSION

The needle tolerances for the inside diameter and length between the manufacturers was close enough to expect no significant difference as was shown by the multiple regression analysis.

The trend that, within a gauge, the longer needle had a faster flow rate than the short was an unexpected finding. The magnitude of this trend of differences is not significant at the 95 percent level of confidence, except for the 25 gauge needles, and is attributable to chance and experimental variation.

Rate of flow is defined in Poiseuilles Law as a function of volume per centimeter per second. By calculation, the interior lumen of the 25 gauge short needle will accomodate a volume of 2.3 cubic millimeters of blood. The 27 gauge long or the 30 gauge needles will respectively accomodate 1.8 cubic millimeters and .83 cubic millimeters of blood. The effect of this volume difference is that, in the smaller gauge needles, the aspirate appears faster but is of less volume.

If one has ever siphoned liquid with a hose, the observed flow rate trend is not surprising. It takes a good deal more effort to start the siphon action with a large diameter hose than with one of a smaller diameter.

The clinical significance of this volume-speed difference between gauges cannot be determined from the finding of statistically significant differences in this experiment. This experiment measured only the speed of aspiration and found statistically significant differences that cannot be interpolated to clinical applications. Volume was not measured.

The aspiration was terminated immediately when the first visible amount of blood entered the carpule. It was apparent, to the investigator, that when aspiration did occur with the larger needles a subjectively greater amount of blood entered the carpule. It therefore is pertinent that when using smaller gauge needles one be more attentive for the positive appearance of aspirate.

The aspirating syringe was utilized to have the lab test simulate the clinical situation. It must be realized that the dental syringe does not represent a perfect method for creating a negative pressure. One should not, therefore, compare this experiment to one which would attempt to elininate all mechanistic variables to show the validity of Poiseuilles Law.

Poiseuilles Law explains the basic principle on which the aspirating syringe functions. Variables such as flexibility of the harpoon-stopper engaging mechanism, the variability of the frictional resistance of the rubber stopper within the glass carpule, and the imperfect fixation of the carpule itself within the syringe are not considered.

It is not surprising, with all these variables, that the findings of this experiment differ from the findings and speculations of other authors on the relationship of Poiseuilles Law and the function of the dental anesthetic syringe.[12,15,19]

The effect of needle radius has been the primary consideration for comparison between different gauge needles. The effect of the radius to the fourth power can be used for comparative purposes only if it is the only variable involved with all other secondary variables eliminated in the experimental design. The use of the dental syringe as the aspirating device does not eliminate the secondary variables.

The cursory examination of the breakage potential of disposable needles was rewarding in showing a good deal of manipulation would be needed to break a needle. It should also be noted that while the 25 gauge needle of the first manufacturer, which broke with the least amount of articulation, was still more difficult to bend than the smaller gauge needles. Needle fracture in a patients mouth is highly unlikely provided needles are not reused and therefore subject to corrosion and weakening of wall strength. Once bent, any needle should be discarded prior to any further soft tissue penetration.

CONCLUSIONS

The following conclusions are made from this investigation:

1. Positive aspiration is always attainable with 25, 27, and 30 gauge needles in vitro.

2. At the 95 percent level of confidence, the 25 gauge short needle showed a significantly slower rate of flow in comparison to the 25 gauge long, 27 gauge short, 30 gauge, and 27 gauge long needles.

3. At the 99 percent level of confidence, the rate of flow of the 25 gauge short needle was significantly slower than the rate of flow of the 27 gauge long or the 30 gauge short needles.

4. Fracture of disposable local anesthetic needles requires multiple repetitious bends.

TABLE I

INSIDE DIAMETER AND LENGTH OF NEEDLES

NEEDLE GAUGE	BRAND	LENGTH CM.	MEAN CM.	DIAMETER MICRONS
30S	1	4.87	0.0152	152
30S	2	4.26	0.0127	127
27S	1	4.54	0.0203	203
27S	2	4.23	0.0203	203
27L	1	6.20	0.0203	203
27L	2	5.48	0.0203	203
25S	1	4.56	0.0254	254
25S	2	4.29	0.0254	254
25L	1	5.77	0.0254	254
25L	2	5.46	0.0254	254

TABLE II

DEGREES OF BENDING TO FRACTURE NEEDLES

BRAND	GAUGE-LENGTH	MEAN DEGREES
1	30-S	342°
2	30-S	414°
1	27-S	288°
2	27-S	396°
1	27-L	288°
2	27-L	459°
1	25-S	297°
2	25-S	477°
1	25-L	324°
2	25-L	369°

CHART I

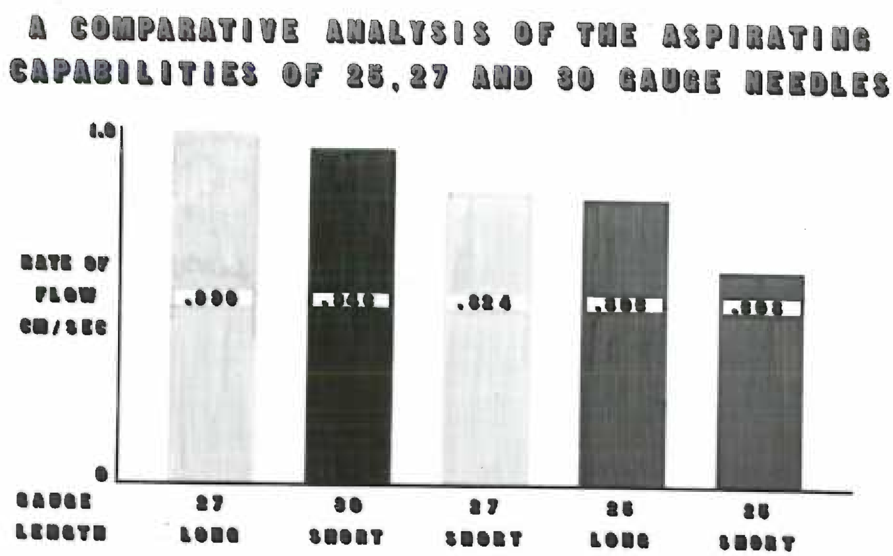
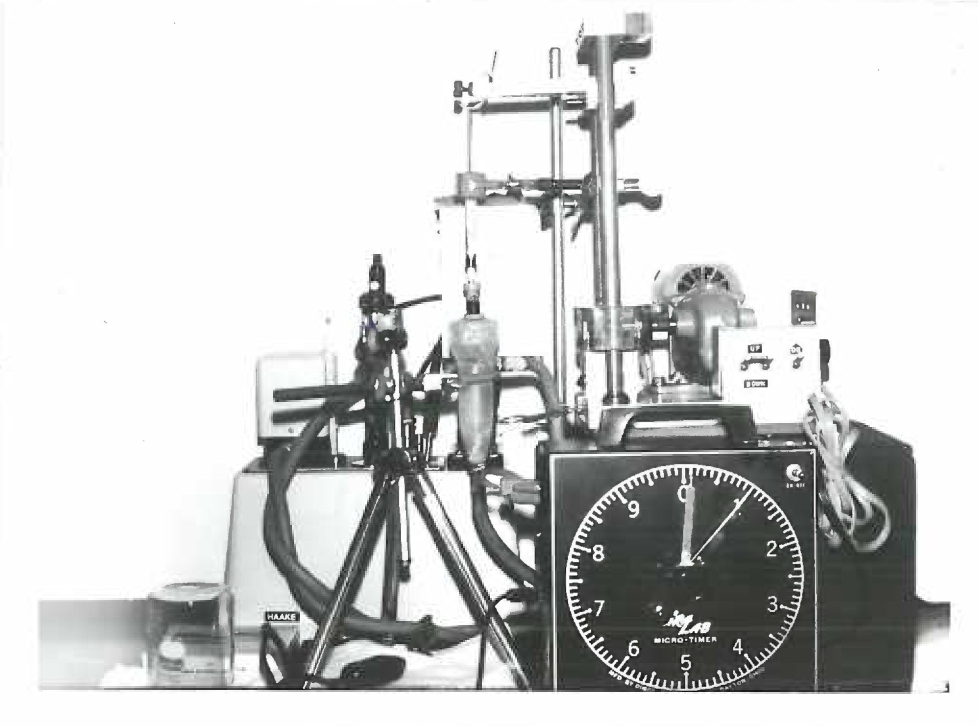

A COMPARATIVE ANALYSIS OF THE ASPIRATING CAPABILITIES OF 25, 27 AND 30 GAUGE NEEDLES
1.0
RATE OF FLOW CM/SEC
0
.824
GAUGE
LENGTH
27
LONG
30
SHORT
27
SHORT
25
LONG
25
SHORT

PHOTO I - TESTING APPARATUS



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