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REENGINEERING THE VERESS NEEDLE FOR LAPAROSCOPY

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ABSTRACT

The aim of this research study was to design an enhanced Veress needle that while maintaining its ability to access the peritoneum without causing vascular or organ damage, it could also achieve two further goals. The first objective was to allow for the passage of a guide wire directly through the needle without requiring dismantling of the inner dull stylet and the outer sharp cannula. The second objective was to increase the flow rate of intravenous fluid into the abdominal cavity. Four modified Veress needles were tested in this study. A thick diameter Veress needle with an outlet along the side of the tip modified the angle of the guide wire by 19.1^0. This Veress needle also exhibited the highest flow rates of 0.416 ± 0.023 mL/sec and 1.668 ± 0.007 mL/sec with and without a drip chamber, respectively. However, this Veress needle required additional force when puncturing the epidermis of a pig belly at angles of 45^0 (64.4 ± 1.6 N) and 90^0 (117.3 ± 2.3 N).

INTRODUCTION

Peritoneal dialysis catheter placement by interventional radiologists and nephrologists is an increasing option for dialysis access for programs in North America. There are numerous technical options for performing this procedure. One of the challenges is safe access to the abdominal cavity which is why the Veress needle is commonly used. The Veress needle has demonstrated historically a very low risk of complications in laparoscopic procedures [1].

The aim of this research was to enhance the design of the Veress needle by increasing the flow rate and allowing the direct passage of a guide wire while maintaining the original needle's safe properties.

METHODOLOGY

Four unique Veress needles were designed with two different diameters. The thin diameter Veress needles featured an outer diameter of 0.083", an inner diameter of 0.063", and a wall thickness of 0.008". The two thin diameter Veress needles had an outlet either at the tip of the needle (Figure 1A) or an outlet along the side of the Veress needle's tip (Figure 1B). Figure 1C shows the side outlet for the thin diameter Veress needle.

Figure 1. The thin diameter Veress needles: A) The thin diameter Veress needle with the outlet along the tip. B) The thin diameter Veress needle with the outlet along the side of the tip. C) A close-up of the thin diameter Veress needle with the outlet next to the needle's tip.

In contrast, two additional Veress needles were created that featured a thicker diameter (Figure 2). These modified Veress needles had an outer diameter of 0.109", an inner diameter of 0.083", and a wall thickness of 0.012". The two thicker Veress needles either had the outlet along the tip of the needle (Figure 2A) or along the side of the tip (Figure 2B). Figure 2C illustrates the side outlet along the tip of the thick diameter Veress needle.

A)
B)
C)

Figure 2. A) The thick diameter Veress needle with the outlet at the needle's tip. B) The thick diameter Veress needle with the outlet along the side of the needle's tip. C) A close-up of the thick diameter Veress needle's outlet along the side of the tip

To assess the needles, three parameters were evaluated: the angle of the guide wire that exited each needle's outlet; the flow rate of each needle; and each needle's puncture force. To measure the angle of the guide wire exiting the outlet, a 0.038" diameter guide wire (Bard Access systems, Salt Lake City, UT, USA) was inserted into each Veress needle.

In regard to analyzing the flow rate, an IV bag filled with water was held 0.75 m above each Veress needle. Two different IV tubes were connected between the IV bag and the Veress needle to determine the extent of how much a drip chamber affected the flow rate. The first IV tube featured a drip chamber (CONTINU-FLO Solution Set, Baxter, Deerfield, IL, USA) near the IV bag and the second IV tube did not feature a drip chamber (924 Pump Set, Covidien, Mansfield, MA, USA). The amount of water that flowed through the Veress needle into an empty beaker over a 30 second period was recorded. This process was repeated three times for each Veress needle.

To measure the puncture force, the Veress needles were fixated onto an Instron 3366 load frame (Instron, Norwood, MA). The needles punctured a slab of pig belly tissue that was approximately 4 cm thick as shown in Figure 3. The Veress needles punctured the tissue at angles of 45º and 90º (vertical) at a speed of 100 mm/min [2].

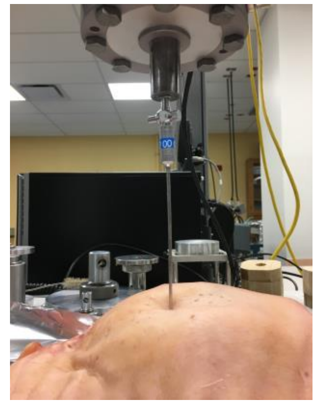

Figure 3. Force puncture test of the Veress needle with the Instron 3366 load frame.

The statistical analysis for this investigation was conducted using SPSS 24 (Chicago, IL, USA). The Shapiro-Wilk test was conducted to test for the normality of the flow rates and puncture forces. Depending on the normality of the data, an independent t-test was performed to identify significant differences for the normally distributed data sets whereas the Mann-Whitney U test was conducted to identify significant differences for the nonparametric data sets ($\alpha = 0.05$).

RESULTS

The guidewire was inserted into each Veress needle and the exit angle was measured. Table 1 lists the exit angles for the guide wire when inserted into the four Veress needle designs.

Table 1. The exit angle of the guide wire.

Needle Size	Outlet Location	Angle of the Guide Wire
Thin	Tip	0º
	Side of Tip	19.8º
Thick	Tip	0º
	Side of Tip	19.1º

The next part of this study analyzed the flow rates of the four Veress needles with and without the drip chamber; this is summarized in Tables 2 & 3, respectively. As shown in Tables 2 and 3, greater flow rates were discovered for the thicker diameter Veress needles and the Veress needles with the outlet along the side of the tip. When comparing Tables 2 and 3, the removal of the drip chamber when connected to the IV tube greatly increased the flow rates. When analyzing whether or not to use the drip chamber, significant differences were found for the thin Veress needles with the outlet at the tip ($p = 0.046$) and along the side of the tip ($p < 0.001$). This also applies to the thick Veress needles such that the needles with the outlet at the tip ($p < 0.001$) and along the side of the tip ($p = 0.046$) had significant differences.

Table 2. Flow rates of the Veress needles with a drip chamber.

Needle Size	Outlet Location	Flow Rate (mL/sec)
Thin	Tip	0.367 ± 0.003 mL/sec
	Side of Tip	0.389 ± 0.009 mL/sec
Thick	Tip	0.399 ± 0.007 mL/sec
	Side of Tip	0.416 ± 0.023 mL/sec

Table 3. Flow rates of the Veress needles without a drip chamber.

Needle Size	Outlet Location	Flow Rate (mL/sec)
Thin	Tip	1.052 ± 0.007 mL/sec
	Side of Tip	1.221 ± 0.004 mL/sec
Thick	Tip	1.329 ± 0.004 mL/sec
	Side of Tip	1.668 ± 0.007 mL/sec

When the drip chamber was used (Table 2), significant differences were found between the thin and thick Veress needles with the outlet at the tip ($p = 0.046$), the thin and thick Veress needles with the outlet along the side of the tip ($p = 0.046$), and the thin Veress needles with the outlets positioned at the tip and along the side of the tip ($p = 0.046$). When the drip chamber was removed from the IV tube (Table 3), there were significant differences detected between the thin and thick Veress needles with the outlet at the tip ($p < 0.001$) and the thin and thick Veress needles with the outlet along the side of the tip ($p < 0.001$). There were also significant differences discovered for the thin Veress needles with the outlets at the tip and along the side of the tip ($p < 0.001$) and the thick Veress needles with the outlets at the tip and along the side of the tip ($p < 0.001$).

Table 4 presents the puncture force of the Veress needle on the pig belly tissue when applied at angles of 45º and 90º. Despite the difference in the angle of application, the thicker Veress needles required more force than the thinner Veress needles. A significant difference was discovered between the thin and thick Veress needles with the outlet at the tip when applied at 90º ($p = 0.007$). Another significant difference was discovered between the thin and thick Veress needles with the outlet along the side of the tip when applied at 90º ($p < 0.001$).

Table 4. The puncture force of the Veress needle at 45º and at 90º.

Needle Size	Outlet Location	45^0 Angle Force	90^0 Angle Force
Thin	Tip	52.8 ± 5.7 N	69.5 ± 6.6 N
	Side of Tip	59.8 ± 8.0 N	67.8 ± 6.7 N
Thick	Tip	59.7 ± 9.0 N	105.3 ± 9.9 N
	Side of Tip	64.4 ± 1.6 N	117.3 ± 2.3 N

DISCUSSION

One critical issue of the Veress needle is the amount of time to administer 1 L of IV fluid into the patient's abdomen. This can be very inconvenient for the patient, the physician, and the nursing staff. Although we hypothesized that the drip chamber can reduce the flow rate, we were surprised that this was a significant limiting factor. For the thin diameter Veress needle with the outlet at the tip, this would take approximately 45 minutes to have 1 L of IV fluid flow into the patient's abdomen. When the drip chamber was removed, this reduces the amount of time to drain 1 L of IV fluid to 15 minutes, which is more efficient. Although the absence of a drip chamber can increase the flow rate, future work needs to be conducted to determine if this is clinically safe.

One of the benefits with the outlet being positioned along the side of the tip of the Veress needle is that the exit angle is modified by approximately 19º. This should help prevent the puncturing of surrounding abdominal tissue; however, we recommend that this should be further tested in animal models.

This investigation revealed that the thicker Veress needles required more force to puncture the epidermis than the thinner Veress needles. This makes sense since the thicker Veress needles have a greater contact surface area. Additionally, the Veress needles with the outlet along the side of the tip required more force to puncture the tissue. Since the Veress needles with the outlet along the side of the tip had a greater contact area with the epidermis than those with the outlet at the tip, more force was required to puncture the tissue. However, we strongly discourage physicians from applying the thick diameter Veress needles at a 90° angle since this may result in accidental injuries.

CONCLUSION

The aim of this project was to develop an enhanced Veress needle for interventional radiologist and nephrologist procedures. To achieve this goal, there were two challenges that needed to be met: develop a method to allow for the passage of a guide wire throughout the stylet and to increase the flow rate of the Veress needle.

We were able to demonstrate we could create a Veress needle that allowed the passage of a guide wire as well as improve the flow rate due to an increased outlet diameter.

Upon removing the drip chamber, this investigation revealed that the drip chamber was a critical limiting factor for administering 1 L of IV solution into the patient's abdomen. When comparing the different needles, the thicker diameter Veress needles had a higher flow rate in comparison to their corresponding thinner diameter needle.

From this investigation, there is promise for the usage of the thick Veress needle with the outlet along the side of the tip. Further studies are required to refine the design and assess the needle when applied in a clinical setting.

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