J-tip Blood Channel Fluid Dynamics Simulation

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Abstract: *Deoxygenated blood travels from the jugular veins to the heart. Due to Lemierre syndrome and blood clot development, blood cannot flow through these veins, which resemble a J-tip blood channel. In this study, jugular veins were shown to have a J-tip blood channel with an interior diameter of 5 millimeters. The flow control through a J-tip blood channel was estimated using fuzzy principles. A simulation of the estimated result has been carried out in ANSYS FLUENT. 305 milliliters per minute by Fuzzy and 304.6 milliliters per minute at a velocity of 2.913 meters per second and pressure of 4.717 x 10^3 Pa by ANSYS are determined flow rates. Comparing simulated data to previously reported data reveals consistency.*

Keywords: Jugular vein, Lemierre syndrome, MATLAB Fuzzy, ANSYS Fluent

1. INTRODUCTION

The neck is where the jugular veins are located. Blood from the brain, face, and neck is collected in these veins [1]. Through the superior vena cava, they deliver blood to the heart [2]. Infectious thrombophlebitis of the internal jugular vein is referred to as Lemierre's syndrome. It most frequently occurs in young, healthy persons as a side effect of a bacterial sore throat infection. Thrombophlebitis is a dangerous disorder that can result in septic emboli or other systemic consequences such as bloodborne infections. The most common cause of this illness is a bacterial throat infection that develops into a peritonsillar abscess. Anaerobic bacteria can thrive deep within the abscess. Internal abscess wall rupture causes bacterial-laden drainage to leak through the soft tissue and infect adjacent structures. Bacteria can enter the bloodstream by an infection that spreads to the neighboring internal jugular vein. Bacteria entered the bloodstream as a result of a throat infection and the development of anaerobic bacteria. The result of this inflammation is a blood clot. This sick clot can now obstruct a pulmonary artery branch. Heart failure is brought on by this artery, which carries blood to the heart and lungs. These veins then start to stand out [1, 2]. S. Mudd and S. B. Grant (1919) first brought up a throat infection [3]. Human necrobacillosis was described by R. R. Gomes in 2022 and is now known as Lemierre's syndrome (a forgotten disease) [4]. Using ANSYS FLUENT [5], Kao et al. (2017) reported the J-tip (jugular veins) flow patterns. Y. L. Hsieh et al. (2021) discovered wall shear stress (WSS) patterns in animal jugular veins using ANSYS FLUENT [6]. Researchers used Fuzzy (Matlab) and ANSYS for simulation of different veins and other areas [7-20]. At various J tips, the flow rate varies in value. Blood flows more quickly when the rate is high enough. The jugular veins of neonates are taken into consideration in this study. For babies, the jugular veins have an interior diameter of 5 mm [21]. These veins have pressure 50 k Pa [22]. Both simulations used in this investigation had these boundary conditions applied to them.

For modeling in this study, J-shaped fluidic channels are taken into consideration for modeling. The numerous J-shaped components that makeup jugular veins are known as J tips. The jugular vein's J tips are depicted in figure 1 below.

The fluidic channel is L in length, D in diameter, R in radius, and P in pressure difference. Viscose-containing blood is moving through this fluid route. The Q flow rate of blood via the fluidic channel is described by the renowned Hagen-Poiseuille equation (1) below [23].

$$Q = \frac{\pi R^4 \Delta P}{8\eta L} \quad (1)$$

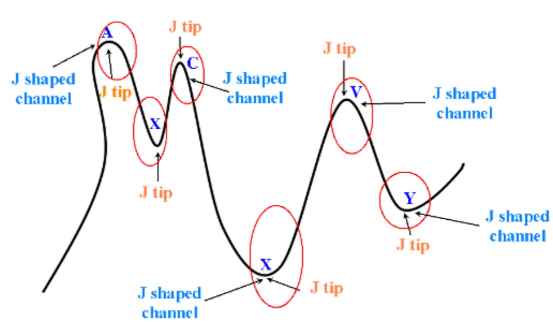

Fig.1. J-tipped jugular veins

Blood is drained into the internal jugular vein from the scalp, brain, superficial regions of the face, and the greater part of the neck [24]. This is the vein's primary function. The inferior petrosal sinus, facial, lingual, and pharyngeal veins, as well as the superior and middle thyroid veins, and even the occipital vein can sometimes be considered to be tributaries of the internal jugular vein.

The right side of the patient's neck is typically examined in order to get an accurate reading of the jugular venous pressure. The most prevalent cause of elevated pulmonary capillary wedge pressure is left heart failure, and elevated jugular venous pressure is a sign of aberrant right heart dynamics. This almost always indicates a fluid overload, which points to the requirement for diuresis [25]. J-Tip is clearly shown in Figure 2.

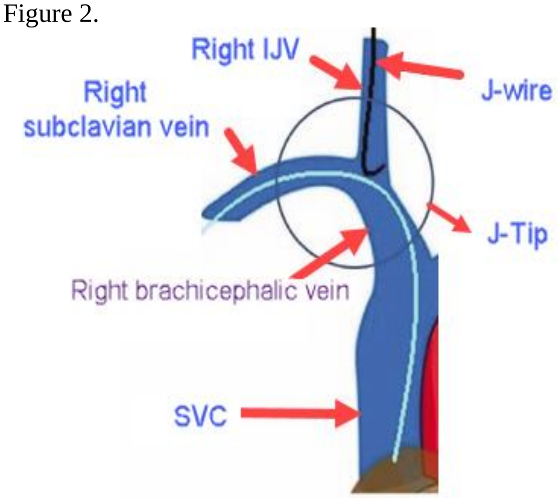

Fig.2. J-tip jugular veins

In order to calculate the pressure, velocity and the flowrate in this vein, either a physical examination or imaging tests make up the bulk of the diagnostic procedures that are performed on the jugular vein. In order to complete this part of the physical examination, you will need to assume a seated position that places your upper body at a particular angle. When examining a patient's jugular veins, a medical professional will check for any signs of edoema or changes in pressure.
The unique aspect of our research is that we were able to calculate the flow rate in jugular veins using MATLAB and ANSYS simulation. The authors used firstly ANSYS and secondly, the Fuzzy technique is used for computations. Blood viscosity is taken as 1060 µPa.s. Numerous researchers have used these simulation techniques in their papers.

2. ANSYS Simulation for the jugular vein

The diameters of this channel are assumed to be exactly equivalent to the J tips of jugular veins for ANSYS simulation. A 4.5 mm internal diameter was assumed. The J-curve tip's radius was likewise assumed to be 4.0 mm. J's straight portion was estimated to be 40 mm. The mesh analysis is carried out following the development of the J-shaped fluidic channel in the design modeler. When creating the 1705 nodes and 1320 elements for the tetrahedron mesh analysis, the relevance was set to 0, the relevance center to fine, and the smoothing to high. Figures 2 and 3 below depict the geometry and mesh.

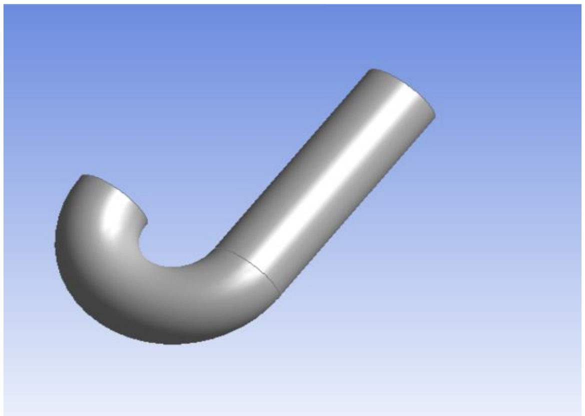

Fig.3. Blood flowing channel with a J-tip in the design modeler

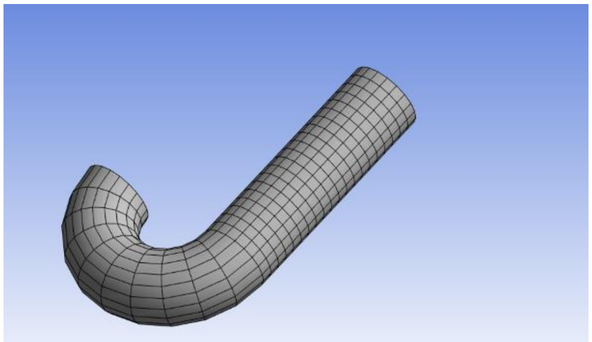

Fig.4. Mesh analysis of a blood fluid channel with a J-tip

Pressure differential and velocity boundaries were established at 500 Pascal to 700 Pascal and 40 meters/second, respectively [1]. Here, blood was envisioned as a flowing fluid with all of its fluidic properties. [2]. The pressure and velocity contours are obtained as a result of the simulation running successfully. Here are the pressure and velocity figures 4 and 5, respectively.

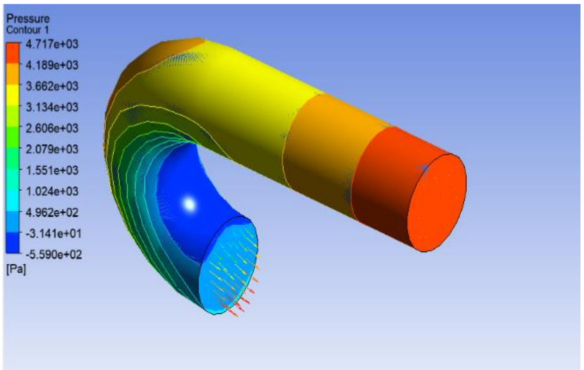

Fig.5. Pressure profile for a fluidic channel with J-tip.

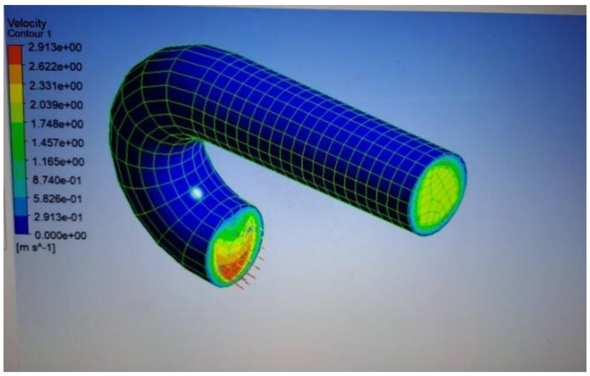

Fig.6. Velocity profile for a fluidic channel with J-tip.

In figure 5, the J-tip curve is colored blue within, while the curve is colored red outside. This suggests that the pressure is gradually lowering. The outside arrows in figure 6's color show that velocity is steadily increasing when looked at more closely. Figures 5 and 6 clearly show how pressure and velocity are inversely related. The following graph in Figure 7 depicts the same story. A graph between flow rate (milliliters/minute) and velocity (meter/second) is also shown in Figure 7. This graph shows how these two quantities are directly related to one another.

Figure 8 shows the flow rate to be 200.0 milliliters per minute at a speed of 40.0 meters per second. When the velocity is increased to 64.67 meters per second, the flow rate rises to 304.6 milliliters per minute. To calculate the flow rate, apply the equation below.

$Q = AV$-----------------------(3)

In the equation above, Q stands for flow rate, A for cross-sectional area, and V for blood velocity [1].

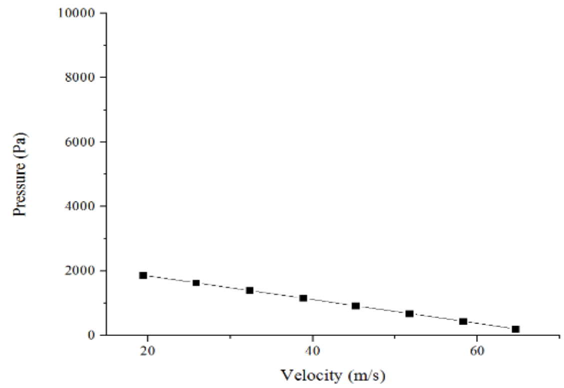

Fig. 7. Pressure versus Velocity Graph

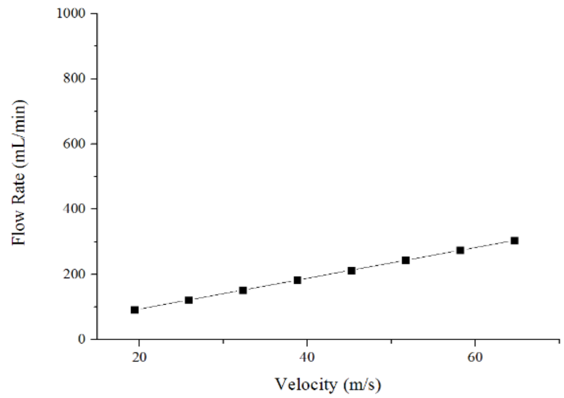

Fig. 8. Flowrate versus Velocity Graph

3. Fuzzy Simulation

The term "fuzzy simulation/analysis" refers to a technique for resolving issues that are associated with ambiguity and unpredictability. This technique is utilised in a variety of fields, including engineering, and it has applications in issues pertaining to decision making, as well as production and planning. In this instance, Fuzzy Simulation introduced a fuzzy logic controller with diameter and pressure as two inputs and one output (flow rate), along with its units. Figure 8. below represents the J-shaped FLC inference system.

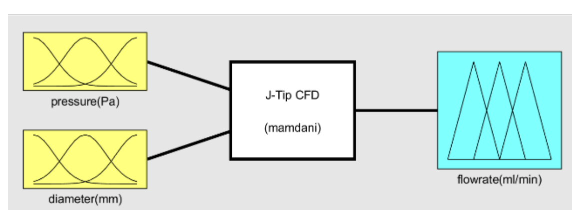

Fig. 9. J-shaped fluid channel FLC editor for fuzzy logic inference system.

According to the actual values of the input and output variables, the ranges for the membership functions

(MFs) in the aforementioned system are assigned. The following table displays this:

Table 1. Ranges of membership functions for all variables

Membership Functions	Diameter (milli meter)		Pressure (Pascal)		Rate of flow ($meter^3$/second)	
	Ranges	Membership Functions	Ranges	Membership Functions	Ranges	Membership Functions
Membership Function 1	4 - 6	small	400 - 600	small	200 - 300	low
Membership Function 2	6 - 7	Med	600 - 700	Med	300 - 350	Med
Membership Function 3	7 - 8	Large	700 - 800	Large	350 - 400	High

Nine rules are created for each input in fuzzy logic. Each input's flow rate is defined for each MF [12]. Hagen-Poiseuille equation [11] states that the flow rate for all rules is well-defined. In Rule Editor, these rules are written, and in Rule Viewer, they are estimated. These rules were developed using the IF-AND-THEN logic. Figure 9 shows the MATLAB rule viewer.

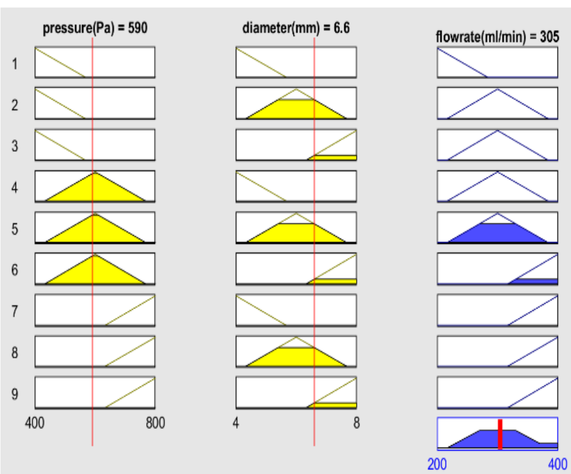

Fig.10. Rule Viewer

Fig. 10 displays the 3-dimensional surface viewer simulation outcome in this case. The relationship between flow rate and diameter and pressure can be seen in this 3D graph.

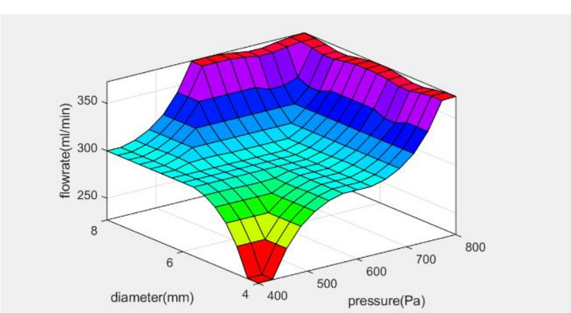

Fig. 11. Surface Viewer's 3D graph shows flow rate, diameter, and pressure.

Mamdani's model is also used to compute flow rate [1-3]. 305 milliliters per minute is the simulated number in the Fuzzy technique, whereas according to Mamdani's model, the actual value is 305.5 milliliters per minute with a 0.163 percent error. The two flow rate figures closely match each other.

4. CONCLUSION

The calculated flow rates are 305 milliliters per minute by Fuzzy and 304.6 milliliters per minute at a speed of 2.1913 meters per second and a pressure of 4.717×10^3 Pa. Through the use of ultrasound dilution technology, in 1998 Leblanc et al. found 300 milliliters per minute jugular vein flow rates at two distinct J-tips. It indicates that simulated data and previously released data are found to be in very close agreement. The authors have completed successful simulations and calculated the blood flow rate for the jugular vein in this work. Therefore, it is understood that simulations using MATLAB Fuzzy and ANSYS Fluent will eventually replace ultrasound dilution technology. These simulations may one day aid in the detection and prevention of diseases.

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