

Chapter 2

A Brief Review of Literature and Objective of the Research

2.1 Literature review

Catheters are an alternative means of facilitating feeding to a patient when oral feeding is impossible for various reasons. If the patient meets with an accident with a severe head injury, has a brain stroke, or is in a comma, etc., a catheter is essentially required. At the time of nasal feeding, a catheter is inserted through the nose and placed into the oesophagus. In such a situation, the objective of the thesis is to investigate how swallowing is affected. Catheters need not be a tube-like structure; there may be a balloon catheter.

Even when a catheter is present in the oesophagus, the fluid is peristaltically driven. Hence, the history of the mathematical investigation of peristalsis is reviewed in the subsequent paragraphs. The literature related to catheterisation follows, however, in detail.

Investigation of peristalsis from mathematical point of view was initiated by Latham (1966), which was subsequently investigated intensively by a large number of researchers that included channel flow and axisymmetric flow and also flows in a curve channel or tube [Burns and Parkes (1967); Fung and Yih (1968); Barton and Raynor (1968); Shapiro et al. (1969); Li (1970); Roos and Lykoudis (1971);

Srivastava and Srivastava (1983); Brasseur et al. (1987); Takabatake et al. (1988); Siddiqui and Schwarz (1994); Elshehawey et al. (1998); Gijssen et al. (1999); Misra and Pandey (2002); Mishra and Ramachandra Rao (2003); Rani and Sarojamma (2004); Elshehawey et al. (2006); Ali et al. (2007); Tang et al. (2009); Shit et al. (2010); Pandey and Tripathi (2010b); Ali et al. (2010); Ali et al. (2011); Tsui et al. (2014); Abbasi et al. (2014); Hayat et al. (2014); Abbasi et al. (2015)].

Shapiro et al. (1969) investigated channel and axisymmetric flow in the wave frame of reference using the long wavelength and low Reynolds number approximations and further discovered reflux and trapping of the bolus in the wave frame. Their pioneer work added new dimensions to research in peristalsis. They defined the existence of fluid particles that travel, on average, in the opposite direction of the net flow near the boundary as reflux. Due to the reflux, the backward migration of the bacteria during urination and the trapping of food bolus happen. Trapping results in the splitting of streamlines and a zone of closed streamlines in the wave frame at high flow rates and large occlusions. This causes some fluid to be trapped within a propagating wave.

Some researchers, however, used perturbation techniques and presented solutions in a series [Fung and Yih (1968); Fung (1971); Srivastava and Srivastava (1989); Ghori et al. (2007); Nadeem et al. (2010); Tripathi (2011); Vajravelu et al. (2012)]. Fung (1971) discussed reflux, which meant average flow reversal. Some solutions using numerical techniques were also provided by a few (Takabatake and Ayukawa (1982), Takabatake et al. (1987) Takabatake et al. (1988)). Newtonian fluid was then replaced by non-Newtonian fluids for analysis to study peristaltic transport. Some research papers aimed to target those parts of the body in order to study anomalies and dysfunctions [Srivastava and Srivastava (1985); Srivastava and Saxena (1995); Srivastava (2007); Srivastava and Rastogi (2010); Maiti and Misra (2013); Alokaily et al. (2018); Akbarzadeh (2018)]. A few [Misra and Pandey (2001); Pandey et al. (2011); Manjunatha et al. (2013); Pandey et al. (2015); Tripathi et al. (2017); Hussain and Ali (2020)] also investigated multi-layered flows. The paper by Brasseur et al. (1987) was worth noting. Based on the correction of the wall equation, which allows contraction and relaxation but no expansion beyond the original boundary, provided by Misra and Pandey (2002), several research papers dealing with various aspects of peristalsis enriched the literature.

In order to investigate experimentally verified pressure in the distal oesophagus Kahrilas et al. (1995), Pandey et al. (2017) analyzed the anatomical measurements reported by Xia et al. (2009), and reported the discovery of dilating wave-amplitude. This led to various investigations on oesophageal flows in the normal and pathological states. They tried to investigate the state of the hiatus hernia as well [Misra and Pandey (2001); Misra (2006); Pandey et al. (2011); Pandey et al. (2015); Pandey et al. (2017); Pandey and Singh (2019); Pandey and Tiwari (2020); Pandey and Chandra (2020); Pandey and Chandra (2022); Pandey et al. (2022); Pandey and Pandey (2024d); Pandey and Pandey (2024b); Pandey and Pandey (2024a); Pandey and Pandey (2024c)].

After him, many researchers continued with their ideas and developed some beneficial knowledge related to peristalsis. Kanai et al. (1970) started to work on catheters for the issues related to blood flow in an artery. Then Roos and Lykoudis (1971) analyzed the problem of peristaltic pumping of ureteral flow with an inserted catheter. This idea has attracted the attention of researchers and contributed significantly. Among the well-known researchers, a few are focused on putting forth their ideas on inserting catheters in the human oesophagus.

Rao and Usha (1995) studied the two immiscible viscous fluids in a circular tube in pumping and co-pumping ranges under long wavelength and low Reynolds number assumptions. They observed that on increasing the viscosity ratio, the volume of a bolus increases in the peripheral layer. They also found that the reflux occurs in the entire pumping range for all viscosity ratios and is absent in the entire range of co-pumping. Later on, Pandey and Tripathi (2010a) studied the peristaltic transport of a viscous fluid under the influence of a magnetic field through a tube of finite length in a dimensionless form. They investigated the effects of the transverse magnetic field and electrical conductivity (i.e., the Hartmann number) on the mechanical efficiency of a peristaltic pump. They concluded, on the basis of the pressure distribution along the tubular length and pumping efficiency, that if the transverse magnetic field and the electric conductivity increase, the pumping machinery exerts more pressure for pushing the forward. Their conclusion, when applied to oesophageal swallowing, reveals that normal water is easier to swallow than saline water.

Kahrilas et al. (2008), opines that the sensitivity or reproducibility of catheter grading and measurement of swallowing disorder has been explored only a little.

The limited information implies that catheterization in the oesophageal lumen has no drawbacks, which can sometimes be seen in barium swallow radiography but is likely even more subjective due to more confounding variables. Their study shows that the recent data hints that catheterisation may help to learn more. However, more research is needed. Hence, this thesis is required to study earlier work and enlighten concerned people about new approaches and results in mathematics and biomedical sciences, which may help improve society.

2.1.1 Non-Newtonian fluids

Although some investigations on non-Newtonian fluids have already been referred to in the foregoing sections, a detailed discussion is listed here. A study by Metzner and Otto (1957) started with power consumption for non-Newtonian fluid compared to Newtonian fluid. They studied why the shear rate of a non-Newtonian fluid is important in fixing the rheological or visco-metric behavior of such materials. Their study was concerned with developing a general relationship between impeller speed and the shear rate of the fluid. Their findings were then used to interpret and correlate power-consumption data on three non-Newtonian fluids using a generalized form of the conventional power-number–Reynolds-number plot for Newtonians. They concluded that power requirements for rapidly mixing non-Newtonian fluids are much greater than those for comparable Newtonian materials.

The first and foremost attempt was made by Raju and Devanathan (1972) to study the peristaltic pumping of non-Newtonian fluid. They investigated the flow properties of peristaltic pumping of a power law fluid in a tube with sinusoidal waves traveling down its wall. Their investigations on streamlines near the tube's axis found that they travel parallel to the axis for a higher pressure gradient and form closed loops for a lower one. On the other hand, when examined close to the boundary, a significant deformation is observed.

Further, the study of non-Newtonian fluid was carried forward by Srivastava and Srivastava (1985). They used this study from the application point of view, i.e., peristaltic pumping in the vas deferens and the small intestine. Power-law fluid has been considered for this investigation. They concluded that at a given flow rate, an

increase in the wavelength leads to a decrease in pressure rise and an increase in the influence of non-Newtonian behavior.

Using the perturbation series method, Siddiqui and Schwarz (1994) studied a second-order non-Newtonian fluid. They proposed a model to investigate the mechanics of peristaltic pumping through an axisymmetric conduit. They analyzed various parameters, such as velocity field and the relation between flow rate and pressure gradient, and also compared their results with those of other studies.

Misra and Pandey (1999) carried out an analytical study of a peripheral layer for the two-dimensional flow. The power-law model was used with the wavelength approximations to obtain the solution regarding stream functions. They concluded that the flow rate increases by raising the flow behavior index.

A study of the peristaltic transport in an axisymmetric porous tube was done for power-law fluid by Rao and Mishra (2004). They used Beavers–Joseph and Saffman-type slip boundary conditions to obtain solutions. They discussed the trapping and reflux phenomena for various parameters, such as flow behavior index, Darcy number, Beavers–Joseph constant, etc. Their study also observed a greater pressure rise and fall for a shear-thickening and shear-thinning fluid, respectively.

The investigation of peristaltic transport of non-Newtonian fluid from Hariharan et al. (2008) was done for different wall waveforms, such as triangular, sinusoidal, trapezoidal, multi-sinusoidal, and square waves. They imposed the Fourier series to obtain spatial and temporal-dependent wall-shape solutions. They concluded that the flow behavior index is key in pressure distribution. The maximum pressure gradient is obtained for the square wave and the minimum for the triangular wave.

Past few years many literatures [Tripathi et al. (2010); Pandey and Tripathi (2011); Kavitha et al. (2012); Misra and Maiti (2012a); Tripathi et al. (2014); Pandey and Tiwari (2017); Pandey and Singh (2019)] covered the various aspects of peristaltic transport of non-Newtonian fluid with broad applications in engineering, industrial, and biomedical sciences.

In recent years, some aspects of the peristaltic flow of non-Newtonian fluids were explored. Among them, Saleem et al. (2020) considered the elliptic duct problem to

study the heat transfer mechanism. They used an appropriate transformation to convert the Casson fluid equations into its dimensionless form. They observed a declination in the temperature of Casson fluid as the behavior changed from non-Newtonian to Newtonian fluids. Further, Javed (2021) carried this work for Johnson-Segalman fluid. They investigated the Hall effect in a heated channel with elastic walls. Tanveer et al. (2021) studied the phenomenon of electro-osmosis with non-Newtonian fluid via peristaltic activity. In contrast, Asghar et al. (2022) investigated the effect of electric and magnetic fields on non-Newtonian fluid in channels under peristalsis. Anwar Bég and Roy (2023) studied the behavior of blood during peristalsis by modeling it as a non-Newtonian fluid. The study on the peristalsis mechanism, which includes non-Newtonian third-grade fluid with different fluid characteristics, was done by Choudhari et al. (2024). They simulated slip, electro-osmosis, and chemical reactions to investigate the effects of the liquid property on temperature, velocity, trapping, and concentration. They concluded that a significant reduction occurred in the given parameters due to the different characteristics of the fluid.

2.1.2 Dilating wave amplitude

In experimental investigations, Kahrilas et al. (1995) observed a higher pressure zone in the distal part of the oesophagus. This was discovered as the dilating peristaltic wave by Pandey et al. (2017) by analyzing the reports published by Xia et al. (2009). Since then, it has been used in many research articles due to its application in oesophagus. Recently, articles on swallowing disorders and their pre-diagnosis through catheters have been discussed in Pandey and Pandey (2024d), Pandey and Pandey (2024b), where this concept of dilating wave amplitude is used. The mathematical formulation of the dilating wave amplitude for the higher pressure at the lower oesophageal sphincter is given by Pandey et al. (2017) as

$$H(Z, t) = a - be^{kZ} \cos^2 \frac{\pi}{\lambda}(Z - ct),$$

where H , Z , t , a , b , k , λ and c represent respectively the wall displacement, the axial coordinate, time, the tube-radius, the amplitude of the wave, the amplitude dilation parameter, the wavelength, and the wave velocity.

2.2 Fluid flows in finite length vessels

Fluid flow refers to the movement of liquid or gas within a medium, a pipe, channel, or vessel. The fluid flow behavior is governed by fluid mechanics principles, primarily encapsulated in the Navier-Stokes equations. These equations describe how the velocity field of a fluid evolves over time due to forces such as pressure gradients and viscous stresses. Understanding how fluids behave within confined spaces is crucial for designing efficient systems and understanding natural processes. In this chapter, we discussed the flows which are relevant to this thesis given as follows:

2.2.1 Two-layered flow

Though most visceral organs are single-layered, the gastrointestinal tract has mucosa, submucosa, and circumferential and longitudinal muscle layers. The arteries, on the other hand, are made up of intima, media, and adventitia. Being the only organ capable of being divided into two layers without causing harm to either, the oesophagus makes for an extremely intriguing biomechanical model. Thus, two entire tubes can be obtained by dissecting the muscle layers from the mucosa-submucosa layer.

There are differences between peristalsis, as found in nature, and the analyses described in this chapter. Physiologically, for example, the wall of the structure doing the pumping (the oesophagus, the ureter, etc.) is typically coated with a fluid with properties different from those of the fluid being pumped. Often, one or both fluids are non-Newtonian. However, as a step towards understanding the effect of a fluid coating on the transport, it is interesting to extend the single-fluid analysis to include a two-layered flow with a peripheral layer of different viscosity.

In this context, Srivastava and Srivastava (1982) were the first to discuss the two-layered model for physiological fluid. They investigated the influence of peripheral layer viscosity on flow rates. They modeled the problem of peristaltic pumping in a channel and non-uniform tube. They observed a decrease in the viscosity of peripheral layer fluid, increasing the flow rate for a given non-zero pressure drop.

The flow rate dependency on the peripheral layer may be ruled out for zero pressure drop.

Further, Srivastava and Srivastava (1984) researched a two-layered model with peristaltic blood transport in arteries. In their study, blood was considered to be the suspension of erythrocytes and plasma. They modeled a two-layered fluid, one peripheral and the other core. The peripheral layer consists of Newtonian fluid (plasma), and the core layer is filled with Casson fluid (erythrocytes). They compared their results with the other studies and found that pressure decreases with a peripheral layer, whereas it increases without a peripheral layer.

Brasseur et al. (1987) investigated a two-layered fluid motion and presented a detailed analysis of characteristics and phenomena, such as trapping and reflux. They concluded that a decrease in peripheral layer viscosity resulted in an overall decrease in reflux and trapping. However, by fixing the pressure head, reflux increased.

Netti et al. (1995) discussed the problem related to drug delivery in the case of solid tumors. They supposed that elevated interstitial fluid pressure impacts the physiological barrier on poroelastic solid (tumor). They observed that no appreciable increase of macro-molecular uptake should occur either by an acute or chronic blood pressure increase. Srivastava and Saxena (1995) investigated a two-layered, which comprises Newtonian and Casson fluid in each layer. They modeled the blood flow consisting of erythrocytes and plasma.

Usha and Ramachandra Rao (1997) investigated the model for a two-layered power-law fluid. They determined the interface between the two layers. They observed the free pumping with a negative time mean flow. Further, they found that the volume of trapped bolus decreases with an increase in the rate of shear thinning of both fluids.

In addition, Usha and Rao (2000) studied the peristaltic transport of two immiscible fluids with different viscosities. They investigated the effects of inertia and curvature in 2D channels. For given viscosities, an increase in curvature resulted in a decrease in trapped bolus volume.

The study of a porous medium in a peripheral layer in contact with the Newtonian core region was studied by Mishra and Rao (2005) for a two-dimensional channel. They employed Brinkman extended Darcy equation to model this problem in the porous layer. They observed a decrease and increase in the pumping caused by increasing Darcy number and an increase in shear stress jump constant, respectively. Narahari and Sreenadh (2010) studied the peristaltic transport of Bingham fluid in contact with Newtonian fluid. They observed that for a larger viscosity ratio and smaller yield stress, pumping efficiency is greater.

The biological problem of kidney stones was discussed by Jiménez-Lozano et al. (2011) through the peristalsis. They investigated this with a two-phase flow model. They observed that increasing particle volume fraction affects peristaltic pumping, and the pressure in the contracted part of the ureter increases. Their studies are relevant for physiological flow transportation with industrial applications where peristaltic pumping is used.

Sinnott et al. (2017) discussed the peristaltic transport of a particulate suspension in the small intestine and cited relevant papers before 2017 to support their study. They took Newtonian and Viscoelastic fluids. They used the discrete element and smoothed particle hydrodynamics methods to predict the motion of solids and liquid content. Along the length of the duodenum, they found non-homogeneity of the solids distribution due to this overall propulsive flow mildly affected by the inclusion of solids. The recent work from 2020 till 2023 by researchers in the peristaltic transport of two-layered fluids has been cited in Pandey and Pandey (2024b).

2.2.2 Flows in a diverging tube: application to sliding hiatus hernia

One of the important factors in blood flow is to consider the tapered tube. Peristaltically driven flow in a tapered tube did not get much attention despite its various applications in biomedical sciences. First, the study was conducted by Oka (1973) to read the pressure distribution in a tapered tube with application to blood flow analysis. They investigated non-Newtonian flow, which is characterized by steady flow. They obtained explicit formulae regarding pressure gradients for different cases, such

as the Bingham body, the power-law fluid curve, and the Casson fluid. It is observed that the pressure gradient is not constant along the axis in all these cases, but as the radius of the tapered tube decreases, pressure increases.

Chaturani and Pralhad (1985) studied biorheological application point of view for the tapered tube. They discussed wall shear, angular velocity, and pressure drop and obtained analytical expressions for these characteristics. Their analysis showed that the length ratio and the coupling are interrelated, which was not so in earlier studies.

Further, Misra and Pandey (1995) investigated the Newtonian flow in a tapered tube by showing its dominance in spermatic flow through vas deferens. They employed perturbation techniques to obtain the analytical solution. Their main objective was to put forward the observation of the flow in an axisymmetric peristaltic motion in a tapered tube, which researchers [Gaver and Grotberg (1986); How and Black (1987); Godleski and Grotberg (1988); Ojha et al. (1989)] did not consider in their works of literature at that time.

Chakravarty and Mandal (2000) carry forward the notion of peristaltic flow in a tapered tube by investigating the stenotic condition of arteries. They obtained several results in their study, such as increased tapered angle with narrowing artery resulted in decreased flow rate. Also, impedance grows more with the rising constriction in the lumen of an artery. The researchers such as Liu et al. (2004), Mandal (2005), Sankar and Hemalatha (2007), and Mekheimer and Kot (2008a) also studied the flow in a tapered tube with the symmetric stenotic condition in the lumen of an artery. The results they obtained are similar to those of previous studies.

The problem of the non-symmetric stenotic condition has been investigated by Ahmad et al. (2019). They observed that changing fluid behavior from shear-thinning to shear-thickening impedance diminishes while increasing the axial velocity. Also, with the increase in tapering parameters, the magnitude of sheer stress decreases.

Recently, a study by Pandey and Chandra (2022) showed the application of tapered tubes in the oesophagus. They developed a mathematical model to study the case of a patient who suffers from a sliding hiatus hernia disorder. They consider the oesophageal tube as an exponentially diverging tube at the distal end of the

oesophagus by means of dilating wave-amplitude. They observed that less pressure is required to carry the fluid in the partly or entirely diverged tube.

2.2.3 Flows in an elastic tube

Flow in an elastic tube was discussed by Rubinow and Keller (1972) to study blood flow applications in the human external iliac artery. They found the flux through the tube, which is a function of tube length, inlet pressure, elastic properties, outlet pressure, fluid viscosity, and external pressure. They have shown their results graphically and in good agreement with experimental studies.

Waters and Guiot (2001) investigated a model for umbilical venous flow. They considered elastic tube flow with prescribed external forcing. This external forcing is responsible for the periodic movement of waves. They showed that their results are very much applied to the physiological implications in umbilical vein blood flow.

Pontrelli (2002) has studied the flow in a viscoelastic tube. His model accounted for the viscoelasticity of vessel walls and the inclusion of wall deformation in the radial and axial directions. He concluded that the wall viscosity coefficient and fluid viscosity produced an even greater damping factor and that the natural oscillations are damped in a few time units. Grotberg and Jensen (2004) studied the biomechanics fluid in an elastic tube. They reviewed advances in the fundamental mechanics of flexible-tube flows. For the cardiovascular system, they discussed physiological applications.

Lazopoulos and Tsangaris (2008) studied the viscous flow in deformable walls of an elastic tube. Their works described the numerical behavior of the non-linear elastic membrane inserted in the tube. Their findings showed very little deviation of the non-linear membrane from its original axisymmetric geometry. On the other hand, the linear elastic membrane exhibits comparatively significant curvature in wide regions, much like a circular arc. As a result, compared to the non-linear example, the linear case's recirculation extends over a longer range, and its pressure variation is also less.

Takagi and Balmforth (2011) investigated viscous fluid in an elastic tube driven peristaltically. They obtained numerical solutions for solitary and periodic wave

trains. These solutions were obtained given small and large forcing amplitudes. They concluded that a single wave of high contraction creates a long, inflated bow wave that propels considerable fluid. In contrast, big amplitude periodic waves are characterized by tiny blisters next to lengthy occluded regions of the tube. A large amplitude solitary wave has the maximum pumping efficacy, which is determined by dividing the net fluid displacement by the power input.

Pandey and Singh (2020) investigated the elastic tube flow with an externally applied force, creating a progressive traveling wave. They discussed transmural pressure difference and radial variation of the tube. They obtained the solution using perturbation techniques. They concluded that pressure increases due to the nominal change in the forcing amplitude of the inward radial force.

Recently, Anand and Christov (2021) analyzed the generalized Newtonian flow at a steady low Reynolds number through a slender elastic tube. They applied lubrication theory to their structural problems using Donell shell theory. They obtained solutions using a perturbative approach w.r.t slenderness parameter. The radial displacement of the tube was found to have a consistently valid solution that includes a corner layer and a boundary layer brought about by localized bending close to the clamped ends.

2.3 Objective of the thesis

The idea that binds my thesis is mathematical formulations of swallowing disorders and exploring solutions through catheterisation of oesophagus. The thesis integrates mathematical modeling, fluid dynamics, and computational techniques to address key challenges in introducing a catheter into the oesophagus that carries Newtonian and non-Newtonian fluids driven peristaltically. It provides insight into broader applications of catheter insertion into the human gastrointestinal tract. Results are analyzed, and conclusions are drawn for patients suffering from oesophageal dysfunctions such as sliding hiatus hernia and achalasia.

The main objective of this thesis is to construct mathematical models to address swallowing disorders in the oesophagus that remained ignored or overlooked.

Since the propulsion of the bolus through an oesophagus occurs peristaltically, the focus is on transporting different fluids through catheterized oesophageal tubes. The goal is to unveil knowledge to help pre-diagnose a patient likely to undergo surgical intervention. Another reason for doing that is to address malfunctions, such as oesophageal carcinoma. Then, a prediagnosis can be performed to replicate the case of achalasia with a catheter. Catheterisation is a minimally invasive procedure, meaning it can be performed with minimal discomfort and risk compared to open surgical techniques. This makes it a safer diagnostic option, especially for high-risk patients. It allows surgeons to gather critical data without requiring more invasive exploratory surgeries, reducing recovery time and minimizing complications. According to previous researchers, work has been done on arteries. However, catheterisation in the lumen of the oesophagus (gastrointestinal tract) did not get any further attention. Earlier, no literature on the mathematical models developed in the thesis was available. Given this, there are several more queries for why this study has been taken up for investigation, as given below:

- What happens to the pressure distribution when a catheter is inserted into a patient's oesophagus?
- What is the optimal length of the catheter inside the oesophagus while nasal feeding is required for a patient?
- Will the influence of viscosity on the peripheral layer be more due to the presence of a catheter?
- Whether nasal feeding continues or not, is it safe to feed the patient water or any liquid through the mouth when the catheter is inside the oesophagus?
- What happens in the case of a sliding hiatus hernia when a catheter is inserted for diagnosing purposes?
- Is it still a pressure requirement that is less even if it is catheterized in case of sliding hiatus hernia?
- What will diverging parameters affect pressure distribution in the case of a catheterized oesophagus?

- What will result from the impact of the catheterization on the micropolar fluid flow in the core region of the oesophagus?
- Does the presence of the micropolar parameter affect the pressure distribution?
- Does the broadening of the thickness of a catheter alter the pressure with the micropolar parameter and coupling number?
- What will be the impact of catheterization on Impedence? Will it enhance the pressure more in the case of micropolar fluid compared to Newtonian fluid?
- What will result from the impacts of dilating forcing amplitudes on pressure distribution along the axial length of an elastic oesophageal tube due to the sinusoidal wave forcing?
- Does the transition from pseudo-plasticity to dilatancy of the fluid require more pressure to propel the boluses toward the cardiac sphincter?
- What will happen with the axial velocity profile on decreasing the flow behavior index? Will the trends be the opposite in the case of dilatant fluid?
- Will there be any attenuation or enhancement in the magnitude of radial velocity due to the shear thickening or thinning of the fluids?
- Does the inflation of the balloon catheter increase the pressure up to its guided length?
- At what stages, i.e., insertion, inflation, deflation, or withdrawal of a balloon catheter, will the pressure be maximum or minimum?

As a treatise, this compilation is a consolidated effort to answer the queries and other related aspects of oesophageal peristalsis.
