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The Role of Doppler Ultrasound in Evaluating Resistant Hypertension Driven by Renal Artery Stenosis among Young Males

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Abstract

Background: Young males with underlying renal problems are becoming increasingly concerned with resistant hypertension (RH). RAS causes hindrance of renal perfusion, which induces renin-angiotensin, aldosterone system and worsening of hypertension. Proper diagnosis is very important in order to treat it early. Doppler ultrasound (DUS), has become a non-invasive imaging method that is cost-effective and manageable modality for detecting RAS. Objective: The purpose of the study is to assess the use of Doppler ultrasound in the identification of renal stenosis of the artery as a condition playing role in resistant hypertension among young men, which highlights its diagnostic validity, feasibility and clinical utility. Methods: The cross-sectional study will be performed with young male patients (25-40 years) with the diagnosis of resistant hypertension. Doppler ultrasound will be done on the participants to determine renal artery stenosis, with peak systolic velocity (PSV), renal-aortic ratio (RAR) and resistive index (RI). Data will be compared to find prevalence of RAS among this population and association between Doppler ultrasound results and such clinical parameters like blood pressure levels and renal functioning experiments. Expected Results: We anticipated that a large percentage of resistant hypertension young men to have Doppler ultrasound results indicating renal artery stenosis. The paper seeks to show how Doppler ultrasound is a reliable diagnostic tool in identifying

hemodynamically significant stenosis which may inform early intervention approaches including medical therapy, angioplasty, or surgical repair. Conclusion: Doppler ultrasound is a useful diagnostic test in the assessment of renal artery stenosis in young men with resistant hypertension that is non-invasive. Timely diagnosis of RAS may allow the improvement of hypertension, thus preventing the risks of complications and long-term diseases in the future, including chronic kidney disease and cardiovascular events. By incorporating Doppler ultrasound into clinical screening protocols in resistant hypertension, the clinical outcomes can be improved, and a more cost-effective option to more invasive imaging can be achieved.Rathi, N. (2023). Contribution of ultra-processed foods to urban Indian diets. *Public Health Nutrition, 26*(9), 1905–1916.

INTRODUCTION

Hypertension is one of the most common non-communicable diseases across the globe and is a cause of cardiovascular morbidity and mortality. The World health organization claims that over 1.28 billion adults in the world suffer hypertension and a large percentage of them are either not diagnosed or they are poorly managed [(1)]. Even though it has always been treated as an older age disease, recent epidemiological studies show that hypertension has increasingly become common among young adults, especially among the males. Such a transition is a significant health problem to the population because it is a long-term exposure to high blood pressure and its cumulative impact on the cardiovascular and renal systems [(2)].

In this younger generation, resistant hypertension (RH) is becoming a well-known fact. RH is characterized by blood pressure in the form that it does not drop down to target levels even with an excellent regimen of at least three antihypertensive drugs of varying categories; a diuretic falls under this category [(3)]. RH patients have an extremely elevated risk of unfavourable cardiovascular diseases, such as stroke, myocardial infarction, heart failure, and chronic kidney disease [(4)]. Diagnosis of secondary causes of hypertension is of particular importance, therefore, in young patients where the essential hypertension is less prevalent and there might be possible etiologies of the condition to be reversed. In secondary etiology, renal artery stenosis (RAS) is a well-known, yet often underdiagnosed cause of resistant hypertension. RAS is defined as a hemodynamically important constriction of either or both renal arteries causing a lower renal perfusion pressure and the triggering of renin- angiotensin-aldosterone system (RAAS) [(5)]. Prolonged stimulation of RAAS causes constriction of the blood vessels, sodium and water retention, and the chronic increase of blood pressure in the body.

RAS may later develop into ischemic nephropathy, permanent renal failure, and aggravated hypertension if not treated [6].

RAS has been linked with atherosclerotic disease in the elderly groups; recent evidence suggests that there is a rising number of RAS in youthful patients, especially men, because of the fibromuscular dysplasia (FMD) [7]. FMD is a nonatherosclerotic and noninflammatory arteriopathy, which is associated with abnormal cell proliferation within the arterial wall that occurs in the renal and carotid arteries. In the renal arteries, FMD gives rise to alternate stenotic and aneurysmal segments, which result in the typical string-of-beads Angiographic appearance [8]. RAS secondary to FMD in young men is usually characterized by limited clinical manifestations except for difficult-to-treat hypertension, thus frequently being mistaken with essential hypertension and thus diagnosed late [9].

The renal arteries form laterally at the abdominal aorta at the vertebral level of L1 12 and they are mainly the main supply vessels of blood to the kidneys [10]. When passing through the renal hilum each of the arteries divides into segmental, interlobar, arcuate and interlobular arteries which supply the renal parenchyma and nephrons. Due to the close aortic derivation and the narrow calibre of these arteries, renal arteries are especially vulnerable to structural defects as well as lesions obstructing the flow [11]. Any drop in the renal perfusion pressure is sensed by the juxtaglomerular apparatus, which begins renin release and secondary RAAS. In unilateral RAS, the process causes systemic hypertension and in bilateral illness or use of an isolated functioning kidney one may experience acute renal dysfunction and hypertensive crises [12].

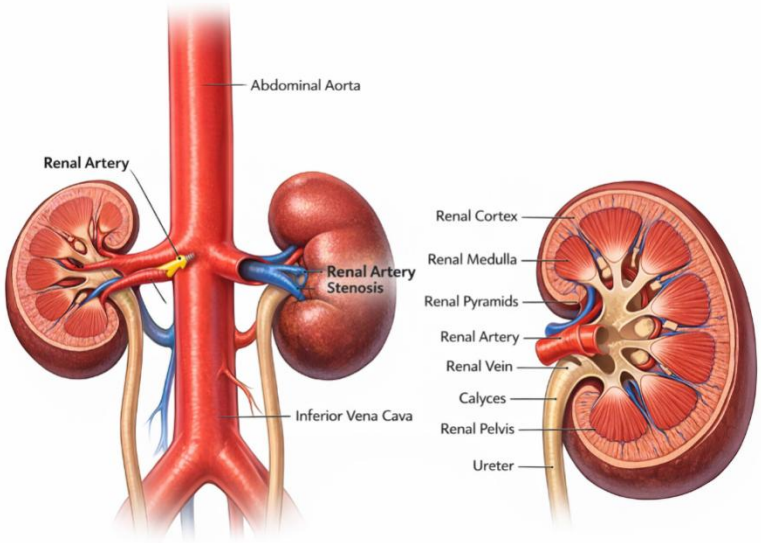

Figure 1.1 Anatomical Structure of the Renal Arteries and Kidneys

The diagnosis of RAS must be accurate and timely especially among young patients with resistant hypertension. Various imaging techniques can be used to assess RAS; such modalities as computed tomography angiography (CTA), magnetic resonance angiography (MRA), and digital subtraction angiography (DSA) can be used. Despite the fact that it is the gold standard, DSA is invasive, expensive, and has some risks like contrast-induced nephropathy and radiation [13]. CTA and MRA are highly diagnostic with the need to use contrast agents and sophisticated infrastructure which restricts its application in young patients who need repeated evaluation as well as in healthcare facilities with limited resources [14].

Doppler ultrasound (DUS) has become a useful, non-invasive modality in terms of assessing the hemodynamics of the renal artery. DUS is used to determine the velocity and waveform patterns of blood flow in the renal arteries and intrarenal branches in real time [15]. Peak systolic velocity (PSV), renal aorta ratio (RAR) and resistive index (RI) are some of the crucial Doppler parameters utilized in the diagnosis of RAS. An RAR of more than 3.3-3.5 and a PSV above 180-200 cm/s is commonly recognized as the presence of the highest degree of at least 60% renal artery stenosis [16] Of these parameters, PSV has exhibited the greatest sensitivity and specificity to reveal hemodynamically significant RAS [17].

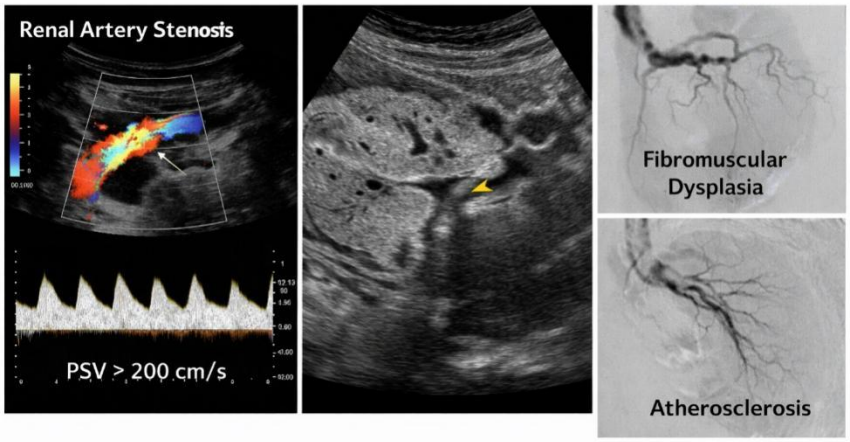

Figure 1.2 Doppler Ultrasound of Renal Artery

Besides direct signs of stenosis, DUS may detect indirect signs of stenosis (post-stenotic turbulence, spectral broadening, and delayed systolic upstroke (parvus-tardus) in intrarenal arteries [18]. RI measurement also offers an understanding of the intrarenal vascular resistance and parenchymal damage supportive in prognostication and

therapeutic decision-making. Additionally, chronic ischemic alterations secondary to long-term RAS are diagnosed by measuring kidney size, cortical echogenicity, and corticomedullary differentiation [19].

The main benefits of Doppler ultrasound are that it is non-invasive, does not contain any ionizing radiation, no nephrotoxic contrast medium is needed, and its cost is rather low. The above characteristics render DUS especially favorable with young hypertensive patients and to be employed in the longitudinal follow-up and screening programs [20]. Nonetheless, it has some shortcomings, including dependence on operators, bowel gas interference, dependence on standardized diagnostic thresholds, and the inability to become a universal first-line screening tool because of its limitations [21].

Since resistant hypertension is increasing among the young males and due to the lack of awareness of RAS among the young males it is in this clinical setting that there is a strong need to conduct diagnostic performance studies on Doppler ultrasound. The proposed research will evaluate various clinical or sonographic variables to evaluate the importance of DUS in diagnosis of renal artery stenosis in young men with resistant hypertension. With the target population being underrepresented, the results of the present study could help to diagnose earlier, maintain a better blood pressure, and save renal functions, as well as decrease long-term cardiovascular morbidity. In addition, the research could also be applied to future research on standardizing Doppler ultrasound regimens and inform clinical guidelines, especially in the resource-constrained care environment [22].

RATIONALE OF STUDY

Renal artery stenosis (RAS) is a highly common secondary cause of resistant hypertension in young males. Clinical presentation is insidious and less commonly used non-invasive diagnostics makes early diagnosis difficult. Although renal angiography is the gold standard, it has limitation as it is invasive and expensive to use on routine basis. The Doppler ultrasound is a non-invasive, available method of assessing renal arterial hemodynamics; although its diagnostic value in this group of individuals is unclear. This paper assesses the importance of Doppler ultrasound in the diagnosis of RAS in young males with resistant hypertension to aid in timely diagnosis and better clinical outcomes.

OBJECTIVES

- To determine whether Doppler ultrasound has a diagnostic value in diagnosing renal artery stenosis in young males with resistant hypertension.
- To examine the prevalence of renal artery stenosis and define the correlation between Doppler ultrasound parameters (PSV, RI, and RAR) and clinical manifestations

of resistant hypertension with the view of evidence-based implementation of Doppler ultrasound in routine clinical practice.

OPERATIONAL DEFINATIONS

1. Resistant Hypertension: The condition of having blood pressure that does not freelance the target level despite taking 3 or more antihypertensive medicines which include a diuretic [24].

2. Renal Artery Stenosis (RAS): This is a disease that leads to constriction of one or both renal arteries, leading to impaired renal perfusion, an increase in the renin-angiotensin-aldosterone system (RAAS), and secondary hypertension [25].

3. Doppler Ultrasound (DUS): This is a non-invasive imaging modality that is applied to assess the flow of blood within renal arteries. Some of the key diagnostic parameters entail peak systolic velocity (PSV), resistive index (RI), and renal aortic ratio (RAR) [26].

4. Fibromuscular Dysplasia (FMD): This is a non-atherosclerotic non-inflammatory vascular disease that results in a segmental constriction of the renal arteries. It is usually associated with younger females although it can also be present in males and thus causes secondary hypertension [27].

5. Peak Systolic Velocity (PSV): This is a Doppler parameter that determines the maximum velocity of blood flow in the renal artery. High values of PSV mean the probability of stenosis worsening [28].

6. Secondary Hypertension: high blood pressure due to a known underlying cause, e.g. stenosis of renal arteries, rather than primary (essential) hypertension [29].

LITERATURE REVIEW

The article by Calhoun et al. (2008) assessed the prevalence and cardiovascular risks. related with resistant hypertension, and occurs in about 10 percent of patients with hypertension. Resistant hypertension is a disease in which blood pressure is not controlled high even in the case of taking three or more antihypertensive drugs, and it is associated to an increased risk of cardiovascular events, to a much greater extent. One of the key findings of the study was that the contraction of renal arteries, usually as a result of atherosclerosis or other secondary type, plays an important role in resistant hypertension. The study noted that young males pose special diagnostic problems due to the decreased rate of atherosclerosis of this population group complicates renal artery stenosis (RAS) to detect early. This helps to emphasize the role of early diagnosis to prevent such complications as heart failure, stroke, damage to kidneys [23].

Tuttle and Anderson (2020) paid attention to the pathophysiology of renal artery stenosis (RAS) among younger patients, specifically young men. They identified fibromuscular dysplasia (FMD) is the primary etiology of RAS in this group. FMD is a

vascular disease non atherosclerotic, non-inflammatory disease affecting renal (blood) arteries, leading to their narrowing. The constriction leads to the stimulation of the renin angiotensin-aldosterone system (RAAS), which increases hypertension. Given the young males having a rare atherosclerosis, RAS diagnosing by standard means can be challenging. This paper identified Doppler ultrasound as a useful diagnostic in younger populations since it is highly accurate and not invasive, tool of detecting RAS. nature, and capacity to track the progression of the disease with time [24] .

Gornik and Persu (2014) in their study went deeper into fibromuscular dysplasia FMD as a major cause of stenosis of renal arteries in young adults, especially males. The paper has highlighted that fibromuscular dysplasia is more likely to result into aggressive different types of resistant hypertension in young men, and in such cases, it might be necessary to resort to special treatment management strategies. The authors talked about the aspect of early diagnosis and intervention is necessary to avoid kidney damage development and to control hypertension effectively. Considering the differences in clinical manifestation, they emphasized the significance of the diagnosis of the imaging techniques includes Doppler ultrasound and CT angiography of renal artery stenosis in this population FMD-related [25].

The study of Zierler (2017) was aimed at finding out the diagnostic value of Doppler ultrasound in identifying renal artery stenosis (RAS). The research pointed out that Doppler ultrasound is a very specific and sensitive technique of identifying RAS, especially among young patients. Given the difficulties of detecting RAS among young men, who usually do not have the non-invasive imaging using Doppler ultrasound is typical risk factors of atherosclerosis crucial. The research contended that Doppler ultrasound was the initial diagnostic instrument since it is a dependable and reproducible way of identifying renal artery stenosis without the dangers of invasive surgeries. This is particularly relevant during youthful age patients, who need to be regularly monitored to monitor the disease progression [26].

Olin and colleagues (2014) were concerned about clinical aspects of fibromuscular dysplasia (FMD) and its effect on the health of the renal artery, especially in younger patients. They explained the importance of early detection of FMD in preventing long term vascular harm and enhancing the control of blood pressure. FMD tends to cause stenosis of the renal arteries, which causes secondary hypertension. The paper has highlighted the importance of early identification by use of imaging techniques such as Doppler ultrasound which can provide significant information about the level of stenosis and assists in determining treatment. The other treatment options that were in the discussion of authors include revascularization procedures that can be

useful in the correction of normal renal blood flow and hypertension control in affected individuals [27].

Whelton et al. (2018) conducted the extensive review of hypertension and multifactorial determinants of it, especially the genetic dispositions that are major contributors of development of hypertension in the young males. The article proposed that genes, alongside the environment, are the cause led to the development of high blood pressure especially among young men. This genetic susceptibility is believed to contribute to the increase of the risk of renal artery stenosis (RAS) and other types of secondary hypertension. The research paid attention to the significance of targeted treatment plans that consider both genetic and environmental influences to deliver enhance blood pressure management among younger hypertensive patients [28] (not older patients).

Bluth et al. (2015) tested the diagnostic precision of Doppler ultrasound in measuring young male renal artery stenosis (RAS). The results were in favor of the usefulness of Doppler ultrasound as an initial diagnostic technique because it is non-invasive and high reliability. The experiment has shown that the Doppler ultrasound may successfully detect even little renal artery stenosis, especially, is of importance in young populations that can be less evidently presented. Additionally, Doppler ultrasound offers real time dynamic imaging, which is important to keep track of disease advancement and measuring treatment efficiency in patients with RAS [29].

Meyer et al. (2019) compared the relationship between the renal artery stenosis and systemic blood pressure among young males. The research determined that even a small stenosis in the renal arteries may cause serious increases in blood pressure. This underlines the significance of the early detection and surveillance because even mild cases of RAS can result in severe influence on the blood pressure. The paper created awareness about the necessity of regularity screening and early treatment to avoid complications like kidney damages and cardiovascular in young hypertension patients [30].

Satter et al. (2021) put their attention into managing resistant hypertension that is a result of renal artery stenosis (RAS) of young men. The research compared the advantages of revascularization measures, such as angioplasty and stenting, and lifestyle interventions, in enhancing results. These interventions are in the case of young males with RAS can be used to reestablish normal flow of blood to the kidneys, enhance control of blood pressure, and prevent chronic renal insufficiency. The researchers found out that the early revascularization together with lifestyle changes give an optimal prognosis to the patients with persistent high blood pressure [31].

Davies et al. (2016) made a comparison between cost-effectiveness of Doppler ultrasound and angiography in the diagnosis of renal artery stenosis (RAS). The research was able to determine that Doppler ultrasound is a very appropriate diagnostic method in young males because it is relatively cheap, non-invasive, and it is safe. Angiography is more accurate in certain instances, but is more dangerous and expensive thus, not preferred in routine screening or monitoring and in younger populations [32].

Johnson et al. (1999) compared two CT angiography algorithms in measuring renal artery stenosis (RAS), real-time volume-rendering and maximum intensity projection (MIP). The authors of the study came to the conclusion that CT angiography is a highly detailed visualization of renal arteries that helps in correct diagnosis of RAS. Volume-rendering algorithm was better in visualization of 3D whereas MIP was better in clarity of image particularly in case of complex cases. The two algorithms were useful in evaluating the structure of the renal arteries in suspected stenosis patients [33].

Oliva et al. (1998) compared the efficacy of Doppler sonography to detect the renal artery stenosis before and after the administration of the captopril. The researchers discovered that Doppler ultrasound, used in combination with captopril, was significantly better than the method of RAS detection. The increase in the systolic velocity of the renal artery flow was an early systolic change which was found to be a useful diagnostic value in identifying functional renal artery stenosis after captopril administration [34].

Riehl et al. (1997) compared duplex sonography and magnetic resonance angiography (MRA) in the detectability of renal artery stenosis. The modalities were sensitive and specific in the diagnosis of RAS, and MRA gave better visualization of renal arteries, especially in complicated cases. However, Duplex sonography was more affordable and non-invasive, and thus it was a diagnostic tool of choice in clinical practice [35].

In the study, Radermacher et al. (2008) compared color duplex ultrasound (CDUS) with quantitative renal angiography (QRA) to examine the severity of renal stenosis of the artery. The results of the study were that CDUS was a valid non-invasive diagnostic measure of identifying RAS; however, quantitative renal angiography offered more comprehensive measurements especially in complicated cases of stenosis. CDUS was a convenient tool to use as routine screening due to its non-invasive nature [36].

This is a new study that Patel et al. (2023) conducted to examine the management of renal artery stenosis (RAS) in young adults with fibromuscular dysplasia. The researchers discovered that a lifestyle change in combination with angioplasty and stenting played a crucial role in the management of blood pressure with reduced

complications [37]. Martinez et al. (2022) examined hereditary indicators of renal artery stenosis in young hypertensive men. The article recommended a greater genetic predisposition among this population and this may have led to the early age and severity of RAS [38].

Lee et al. (2021) considered the high-resolution MRI and Doppler ultrasound as the ways of examining the renal artery stenosis at its early stages in young men. In their results, they found that these technologies were relevant to a significant enhancement in the accuracy of the diagnosis and enabled an improved monitoring of the disease [39]. Zhang et al. (2023) In their retrospective study, they were interested in assessing the diagnostic performance of simple Doppler ultrasound parameters in identifying severe RAS (⩾70%), in the context of regular clinical practice. It involved 85 patients having 106 renal arteries. The main Doppler parameters which were measured included peak systolic velocity (PSV), renal-aortic ratio (RAR), renal-segmental ratio (RSR) and renal-interlobar ratio (RIR). Best thresholds were 249.5 cm/s in PSV, 2.94, 5.1 and 7.5 in RAR, RSR and RIR respectively. A combination of these parameters gave an area under the curve (AUC) of 0.962, which is high diagnostic efficiency. It was concluded in the research that the application of a composite of these Doppler parameters can largely improve the observation of severe RAS in the regular clinical practice and provide a solid foundation upon which candidates can be chosen to undergo further angiography or revascularization [39].

Wang et al. (2024), This experiment formulated a deep-learning model of the computer-aided diagnosis of RAS with multimodal fusion technology under the basis of the ultrasound scanning images, spectral waveforms, and clinical data. One thousand four hundred and eighty-five patients undergoing renal artery ultrasonography were used in the study. A multimodal dataset was used to train three deep learning models (ResNeSt, ResNet, and XCiT). The best accuracy of 83.49 was obtained with the ResNeSt model with accuracy of 81.89 and recall of 76.97. The model had an accuracy of 78.25 compared to the gold standard of the renal artery angiography, which was 90.09; the accuracy of senior physicians was slightly higher. The researchers concluded that the deep-learning models, especially those based on the multimodal data, can be beneficial in aiding the diagnosis of RAS, which can increase the diagnostic accuracy and efficiency in clinical practice [40].

The case report by Vipparala et al. (2020) focused on a patient with resistant hypertension and severe RAS, a patient who had a negative duplex ultrasound. Regardless of the negative DUS, the patient had been diagnosed of having serious RAS on the computed tomography angiography (CTA). The paper has highlighted that more

sensitive imaging, such as CTA, should be taken into account even when DUS results are negative in cases with high clinical suspicion. The authors also came up with the conclusion that although DUS is a useful tool used in the initial screening, it is not capable of detecting all instances of RAS, and other imaging tests are required to accurately determine the diagnosis in some situations [41].

Their article by Qiu et al. (2021) examined the application of ultrasound localization microscopy (ULM) as a method of measuring hypertensive nephrosclerosis in a rat model. The objective of the study was to determine the sensitivity of ULM against conventional ultrasound to identify microvascular changes that are related to hypertensive nephrosclerosis. These findings indicated that ULM was more sensitive to the detection of these microvascular changes. The authors concluded that ULM could provide a more sensitive instrument of early diagnosis of hypertensive nephrosclerosis than conventional ones, which could enhance the outcome of patients with an earlier intervention [42].

The study by Makhija et al. (2018) was a retrospective study that assessed the utility of DUS in screening obese children with hypertension. The researchers analyzed 174 patients, and they evaluated the efficacy of DUS in the detection of RAS. The results showed that DUS was suitable in the detection of RAS and there was no significant difference in the values of the resistive index according to the BMI. The researchers concluded that obesity is not an important factor that influences the usefulness of the DUS in RAS screening, but resistive index on its own cannot be considered a screening tool [43].

Kang et al. (2023) conducted this study and the authors assessed the application of intravascular ultrasound (IVUS) in patients with both hypertension and focal renal artery fibromuscular dysplasia (FMD). This study was meant to establish the additional information that IVUS provides to the diagnosis and management of the FMD related hypertension. The data showed that IVUS is a helpful resource in assessing the structure of the vascular system that would be used in diagnosing and treating FMD-related hypertension. These findings allowed the authors to draw the conclusion that IVUS can serve as additional equipment in the process of measuring RAS due to FMD which can lead to the improved patient outcomes in the relation to more adequate diagnoses and the following treatment plans [44].

The promise of ultrasound-guided renal denervation has been discussed in the current review by Ali et al. (2023) as a way of treating hypertension. In the review, the promise of this non-invasive treatment of hypertension resistant was realized. The authors indicated that the effectiveness and safety of this method must be identified

through additional studies. They concluded that ultrasound-guided renal denervation has a potential of curing resistant hypertension in a completely non-invasive procedure, and the effectiveness and safety profile of the practice should be established in future studies [45].

Zhang et al. (2019) was a research that was conducted in-vitro and tested the appraisal of low-degree (less than 50) RAS on Doppler ultrasound. The research question was to determine whether in the case of low-degree stenoses Doppler ultrasound could identify the variation of velocity and the wall shear stress. These results indicated that Doppler ultrasound was able to pick up these changes. The conclusion that the authors arrived at is that Doppler ultrasound can be used in the diagnosis of RAS at its early stages, which may potentially result into the possibility of early intervention and improved patient outcomes [46].

Garcic et al. (2024) used DUS in a retrospective study to research incidences of transplant renal artery stenosis (TRAS). The researchers used 724 kidney transplant recipients in the study and the aim was to determine the capacity of systematic DUS screening to be effective in detecting TRAS. It was found that 10 per cent of patients diagnosed with TRAS in systemic DUS screening. The authors concluded that the post-transplantation standard DUS can simplify the early detection and intervention of TRAS, and this results in the possibility of improving the survival of grafts and patients [47].

METHODOLOGY

3.1. Research Design: This was a cross-sectional, observational study.

3.2. Clinical Setting: Data was collected from Chaudhry Muhammad Akram Teaching Hospital.

3.3. Sample Size: The expected number of cases (E) in $E = N \times P$

Where:

- N = Total number of patients in the study (45)
- P = Prevalence of RAS in hypertensive patients (colour)

Thus, the expected number of cases is approximately 45.

3.4. Sampling Technique: The sampling technique for this study was purposive sampling, targeting young males with resistant hypertension suspected of having renal artery stenosis.

3.5. Duration of Study: The durations was 04 months after the submission of the synopsis.

3.6. Selection Criteria

3.6.1. Inclusion Criteria

- Patients aged 25–40 years.

• Diagnosed with resistant hypertension.
• Willing and able to provide informed consent to participate in the study.

3.6.2. Exclusion Criteria

• Patients with secondary hypertension due to causes other than renal artery stenosis.
• Females and children.

3.7. Ethical Consideration

Ethical approval was obtained from the institutional ethical review committee prior to the study. Written informed consent was taken from all participants after explaining the purpose and procedure of the study. Participation was voluntary, and participants had the right to withdraw at any time without affecting their medical care. Confidentiality was maintained by assigning unique identification codes, and all collected data were used strictly for research purposes. As Doppler ultrasound is a non-invasive procedure, no significant risk was posed to participants.

3.8. Data Collection Procedure

Patients with resistant hypertension fulfilling the inclusion criteria were recruited during the study period. Demographic and clinical information, including age, blood pressure readings, and medication history, were recorded. Renal Doppler ultrasound was performed using a standardized protocol by an experienced sonographer. Peak systolic velocity (PSV), resistive index (RI), and renal–aortic ratio (RAR) was measured for both renal arteries and documented on structured data collection forms.

3.9. Data Analysis

Data were entered and analysed using statistical software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Doppler ultrasound parameters were used to identify renal artery stenosis based on established diagnostic criteria. Results were summarized using tables and graphs, and a p-value < 0.05 was considered statistically significant.

RESULTS

Originally, the study included 45 young male patients with resistant hypertension; however, 2 patients were excluded due to prior unilateral nephrectomy. Therefore, the final analysis was performed on 43 male patients with intact bilateral kidneys.

Most patients were aged 31–40 years (58.1%), while 41.9% belonged to the 20–30- year age group. Doppler ultrasound demonstrated a high prevalence of abnormal renal artery parameters, predominantly involving the right kidney. Abnormal peak systolic velocity (PSV) was observed in 62.8% of right renal arteries compared to 37.2% on the left. Similarly, abnormal resistive index (RI) was noted in 58.1% of right kidneys and 37.2% of left kidneys. Renal artery ratio (RAR) was abnormal in 62.8% of right renal

arteries and 37.2% of left renal arteries, suggesting a higher frequency of hemodynamically significant stenosis on the right side.

Abnormal systolic, diastolic, and mean arterial pressures were observed in all the patients, and this confirms that they had persistent hypertension that is not under control despite medical treatment. They were all known to have a history of hypertension and are taking antihypertensive drugs and have also diagnosed renal stenosis of the artery. Other related issues were positive family history of hypertension (58.1), smoking (60.5), and chronic kidney disease (37.2) in the patients. All participants declared a headache and dizziness. There were abnormal Doppler results in both groups of ages and even younger patients, which means that renovascular disease occurs in this category at a young age.

Table 4. 1: Age Group

Table and Graph 4.1 show the age distribution of young males included in the study. Most participants belonged to the 31–40 years age group, while a smaller proportion were aged 20–30 years. This indicates that resistant hypertension with suspected renal artery involvement was more frequently observed in the slightly older subgroup of young males.

Age

		Frequency	Percent
Valid	Age group 31-40	25	58.1
	Age group 20-30	18	41.9
	Total	43	100.0

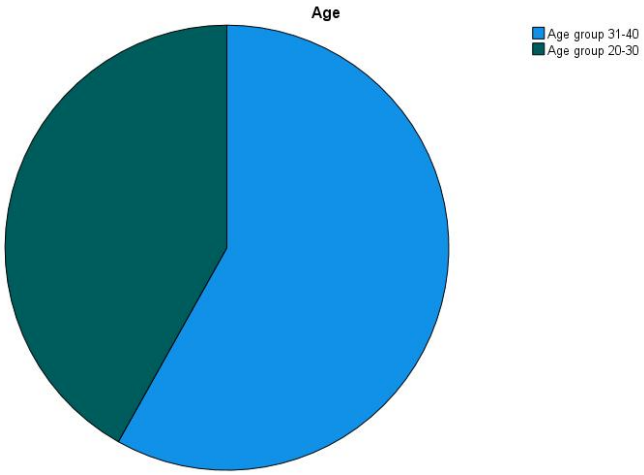

Figure 4.1: Age Group

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Table 4.2: Peak Systolic Value Right Renal Artery

Table and Graph 4.2 present the peak systolic velocity findings of the right renal artery. A greater number of patients showed abnormal values compared to normal readings, indicating increased arterial flow velocities. This suggests a higher likelihood of right-sided renal artery stenosis in young males with resistant hypertension.

Peak Systolic Value Right Renal Artery

		Frequency	Percent
Valid	Normal	16	37.2
	Abnormal	27	62.8
	Total	43	100.0

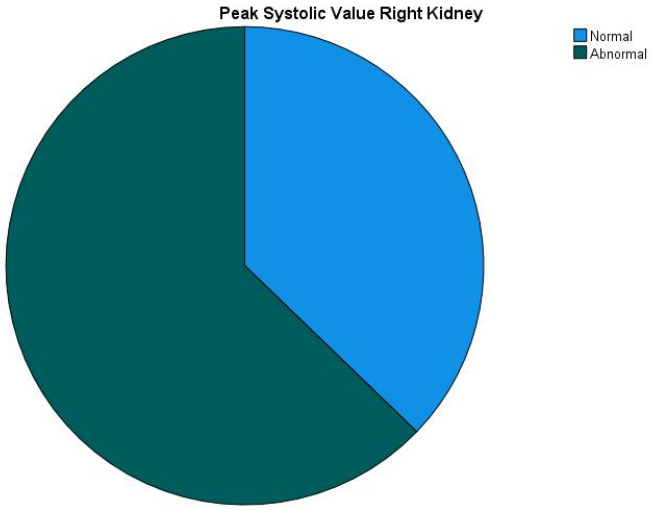

Figure 4.2: Peak Systolic Value Right Renal Artery

Table 4.3: Peak Systolic Value Left Renal Artery

Table and Graph 4.3 show the peak systolic velocity measurements of the left renal artery. Most participants demonstrated normal values, while fewer cases showed abnormal elevations. This indicates relatively preserved left renal arterial flow in the majority of young males with resistant hypertension.

Peak Systolic Value Left Renal Artery

		Frequency	Percent
Valid	Normal	27	62.8
	Abnormal	16	37.2
	Total	43	100.0

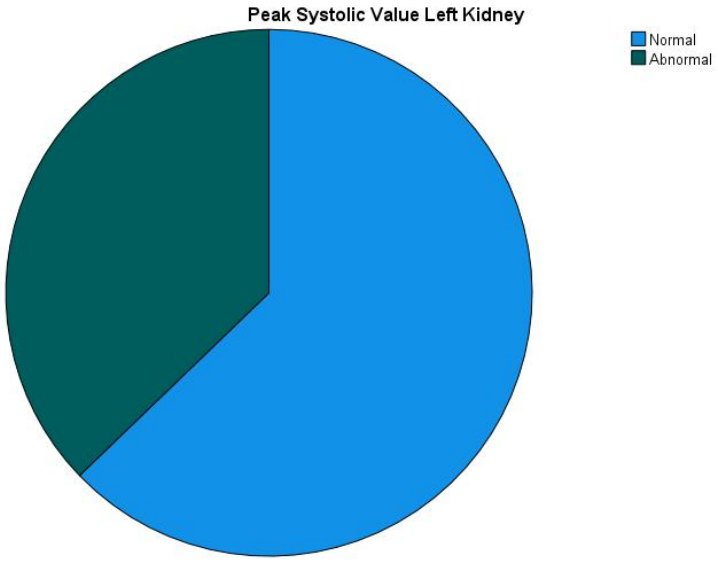

Figure 4.3: Peak Systolic Value Left Renal Artery

Table 4.4: Resistive Index Right Renal Artery

Table and Graph 4.4 illustrate the resistive index values of the right kidney among the study participants. Abnormal resistive indices were observed in more than half of the cases, while normal values were seen in fewer patients. This finding reflects increased intrarenal vascular resistance in young males with resistant hypertension.

Resistive Index Right Renal Artery

		Frequency	Percent
Valid	Normal	18	41.9
	Abnormal	25	58.1
	Total	43	100.0

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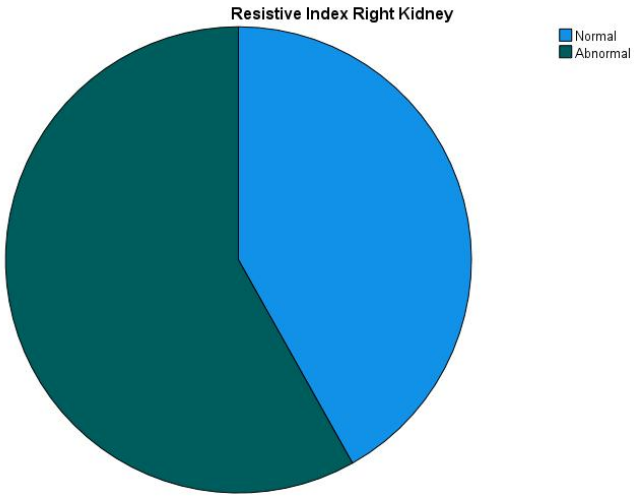


Figure 4.4: Resistive Index Right Renal Artery

Table 4.5: Resistive Index Left Renal Artery

Table and Graph 4.5 present the resistive index measurements of the left kidney. Normal values were observed in the majority of patients, while abnormal findings were seen in a smaller proportion. This suggests comparatively better intrarenal blood flow on the left side in young males with resistant hypertension.

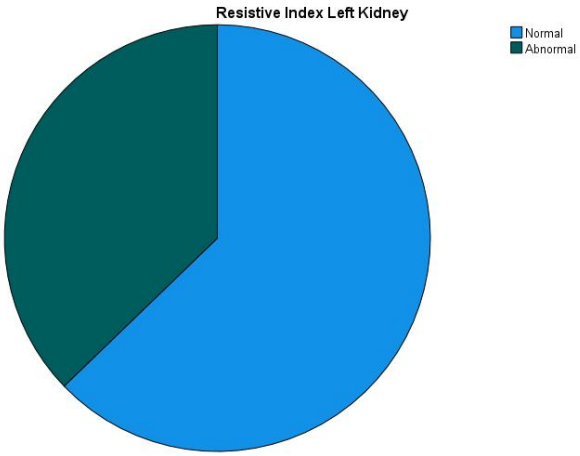


Figure 4.5: Resistive Index Left Renal Artery

Table 4.6: Renal Artery Ratio Right Renal Artery

The table and accompanying graph 4.6 show the distribution of renal artery ratios in the right kidney among the study participants. Out of 43 young males with resistant hypertension, 62.8% had abnormal renal artery ratios, indicating a high prevalence of potential renal artery stenosis, while 37.2% had normal findings.

Renal Artery Ratio Right Renal Artery			
		Frequency	Percent
Valid	Normal	16	37.2
	Abnormal	27	62.8
	Total	43	100.0

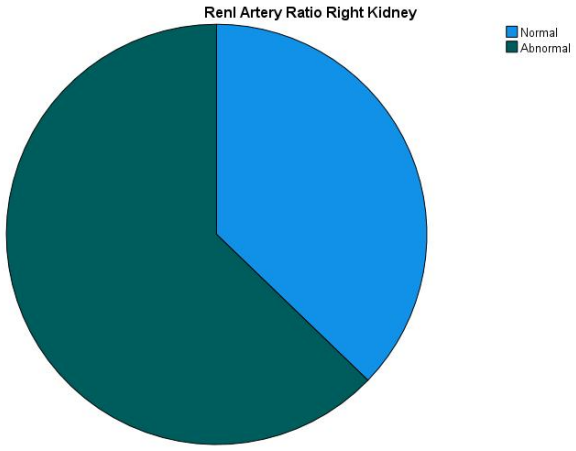


Figure 4.6: Renal Artery Ratio Right Renal Artery

Table 4.7: Renal Artery Ratio Left Renal Artery

The table and graph 4.7 say, among the 43 young males with resistant hypertension, 62.8% showed normal renal artery ratios, while 37.2% had abnormal values, suggesting a lower prevalence of left-sided renal artery involvement compared to the right. This emphasizes the role of Doppler ultrasound in identifying unilateral or bilateral vascular changes.

Renal Artery Ratio Left Renal Artery			
		Frequency	Percent
Valid	Normal	27	62.8
	Abnormal	16	37.2
	Total	43	100.0

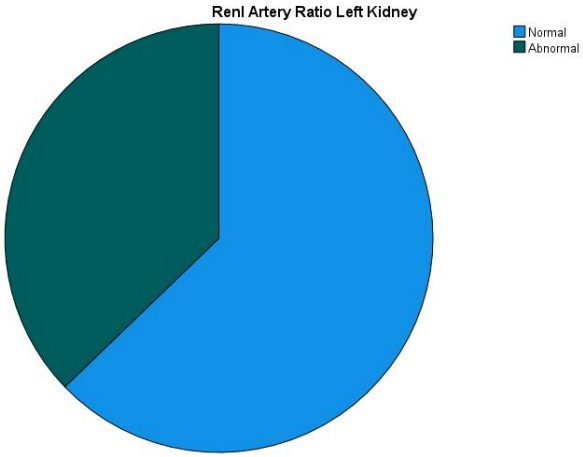


Figure 4.7: Renal Artery Ratio Left Renal Artery

Table 4.8: Mean Arterial Pressure

The table and graph 4.8 show that all 43 participants had abnormal mean arterial pressure, reflecting persistent hypertension despite treatment.

Mean Arterial Pressure			
		Frequency	Percent
Valid	Abnormal	43	100.0

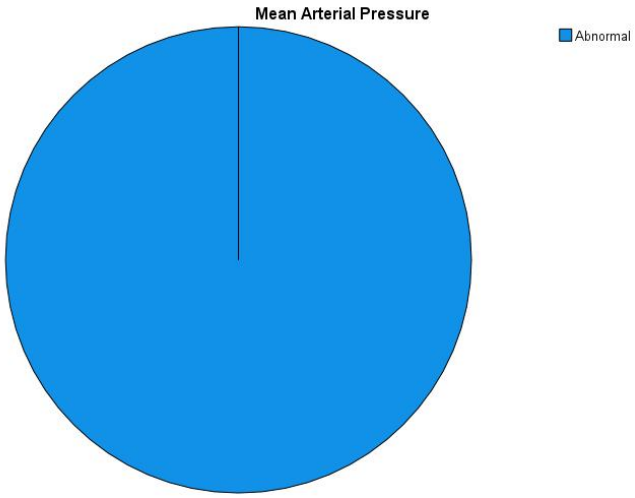


Figure 4.8: Mean Arterial Pressure

Table 4.9: Systolic Blood Pressure

The table and graph 4.9 show that all 43 participants had abnormal systolic blood pressure, confirming uncontrolled hypertension despite ongoing therapy. This consistent elevation emphasizes the resistant nature of hypertension in the study group.

Systolic Blood Pressure

		Frequency	Percent
Valid	Abnormal	43	100.0

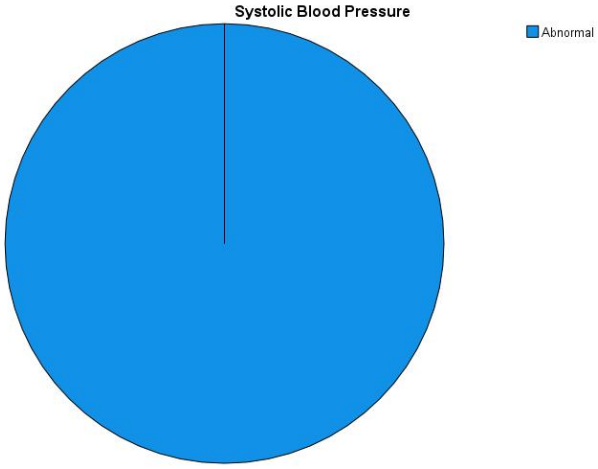


Figure 4.9: Systolic Blood Pressure

Table 4.10: Diastolic Blood Pressure

The table and graph 4.10 show that all 43 participants had abnormal diastolic blood pressure, indicating persistent elevation in both systolic and diastolic readings.

Diastolic Blood Pressure

		Frequency	Percent
Valid	Abnormal	43	100.0

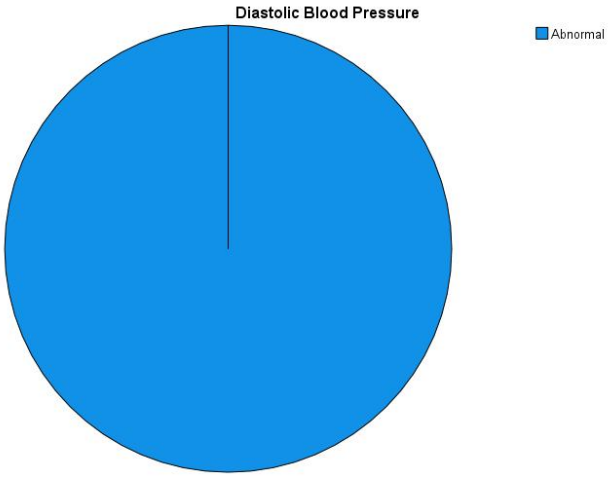
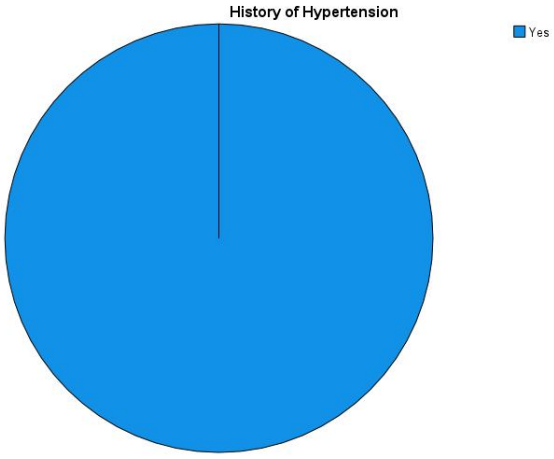


Figure 4.10: Diastolic Blood Pressure

Table 4.11: History of Hypertension

The table and graph 4.11 show that all 43 participants had a documented history of hypertension.

History of Hypertension			
		Frequency	Percent
Valid	Yes	43	100.0



4.11: History of Hypertension

Table 4.12: On Medication

The table and graph 4.12 show that all 43 participants were receiving antihypertensive medication.

On Medication			
		Frequency	Percent
Valid	Yes	43	100.0

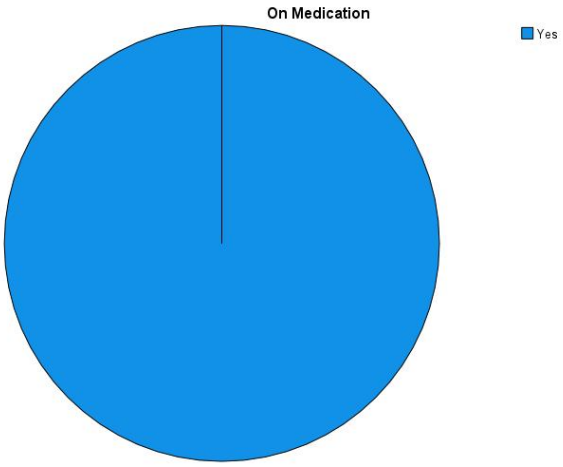


Figure 4.12: On Medication

Table 4.13: Uncontrolled Blood Pressure

The table and graph 4.13 show that all 43 participants had uncontrolled blood pressure despite being on antihypertensive medication.

Uncontrolled Blood Pressure			
		Frequency	Percent
Valid	Yes	43	100.0

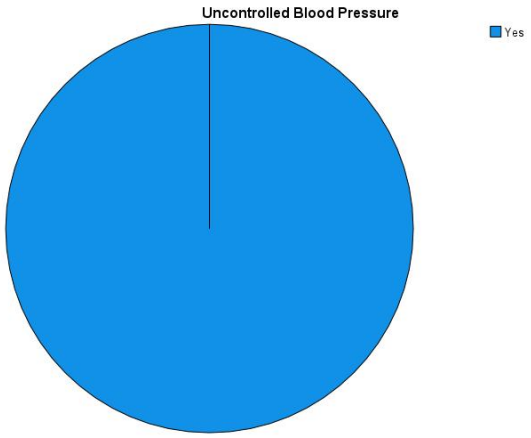


Figure 4.13: Uncontrolled Blood Pressure

Table 4.14: Family History of Hypertension

The table and graph 4.14 show that 58.1% of participants had a positive family history of hypertension, while 41.9% did not.

Family History of Hypertension			
		Frequency	Percent
Valid	No	18	41.9
	Yes	25	58.1
	Total	43	100.0

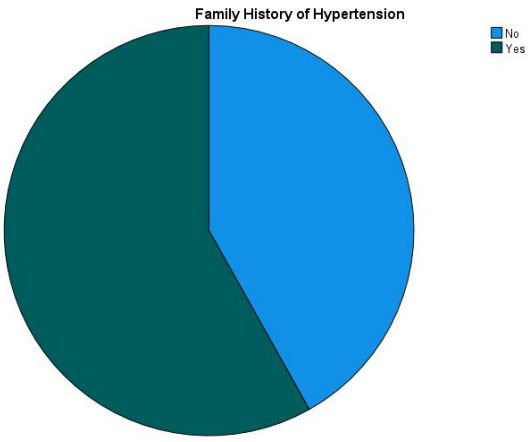


Figure 4.14: Family History of Hypertension

Table 4.15: Known Renal Artery Stenosis

The table and graph 4.15 show that all 43 participants had a confirmed diagnosis of renal artery stenosis.

Known Renal Artery Stenosis			
		Frequency	Percent
Valid	Yes	43	100.0

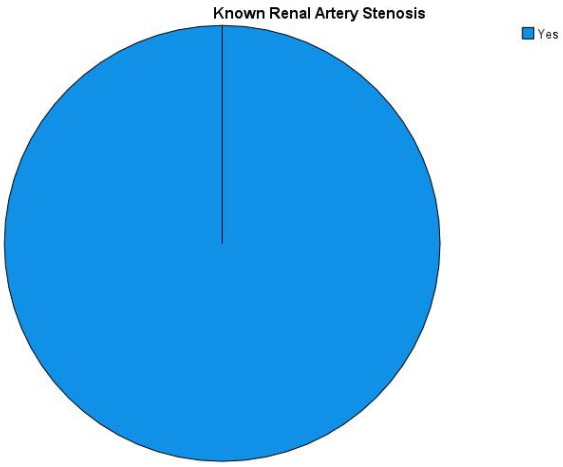


Figure 4.15: Known Renal Artery Stenosis

Table 4.16: Known Chronic Kidney Disease

The table and graph 4.16 shows that most patients (62.8%) did not have a known history of CKD, while 37.2% had pre-existing CKD, highlighting a notable proportion with underlying kidney impairment in this young male population.

Known Chronic Kidney Disease			
		Frequency	Percent
Valid	No	27	62.8
	Yes	16	37.2
	Total	43	100.0

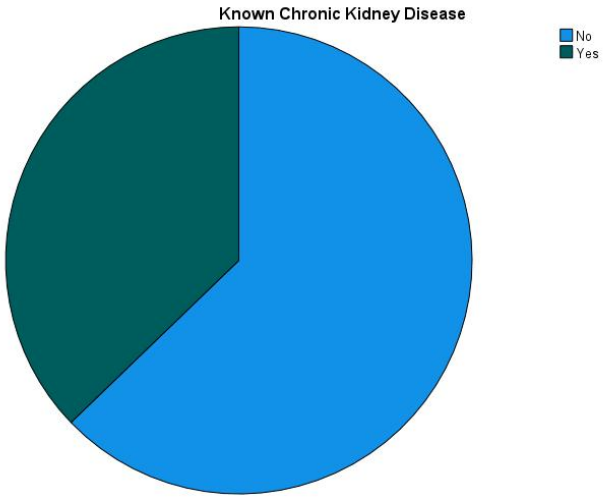


Figure 4.16: Known Chronic Kidney Disease

Table 4.17: Smoker

The table and graph 4.17 shows that majority of patients (60.5%) were smokers, while 39.5% were non-smokers, indicating that smoking is common in this population and may contribute to vascular risk.

Smoker			
		Frequency	Percent
Valid	No	17	39.5
	Yes	26	60.5
	Total	43	100.0

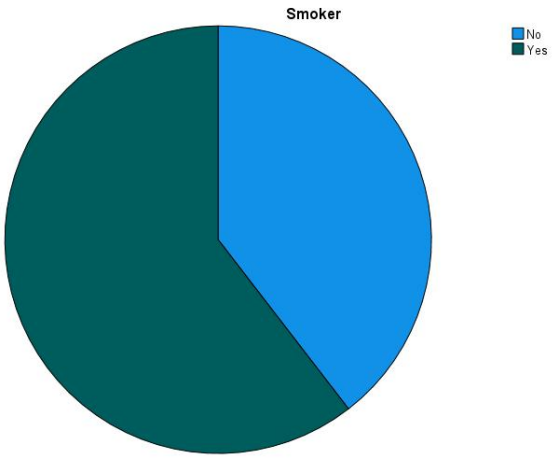


Figure 4.17: Smoker

Table 4.18: Alcohol

In table and graph 4.18, Most patients (55.8%) did not consume alcohol, while 44.2% reported alcohol use, suggesting a considerable proportion with lifestyle factors that may impact vascular health.

Alcohol			
		Frequency	Percent
Valid	N0	24	55.8
	Yes	19	44.2
	Total	43	100.0

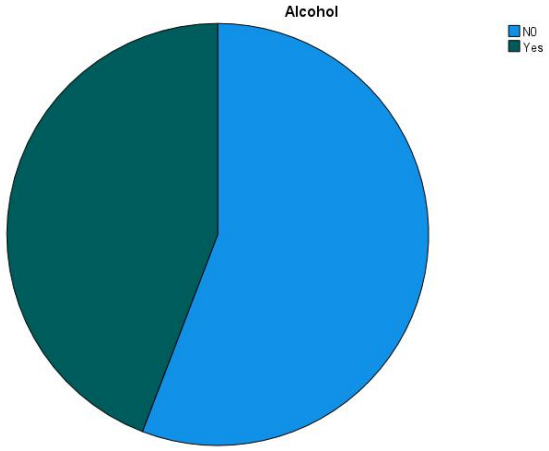


Figure 4.18: Alcohol

Table 4.19: Exercise

The table and graph 4.19, show that all patients (100%) in the study reported engaging in exercise.

Exercise			
		Frequency	Percent
Valid	Yes	43	100.0

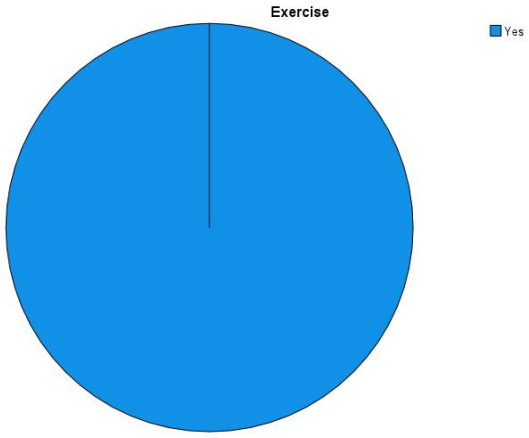


Figure 4.19: Exercise

Table 4.20: Symptoms of Headache and Dizziness

The table and graph 4.20, show that all patients (100%) reported experiencing headache and dizziness.

Symptoms of Headache and Dizziness			
		Frequency	Percent
Valid	Yes	43	100.0

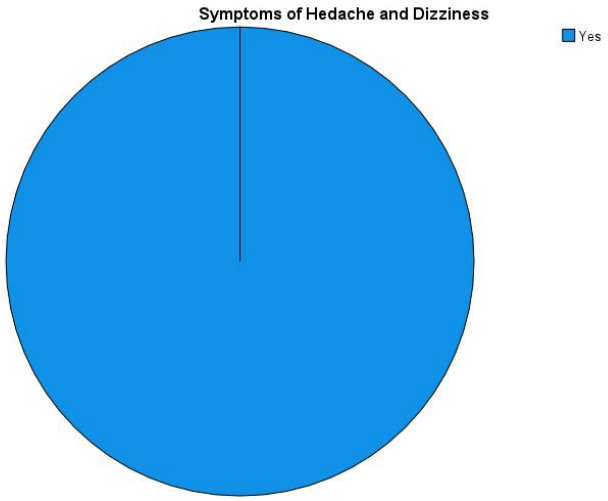


Figure 4.20: Symptoms of Headache and Dizziness

Table 4.21: Age * Peak Systolic Value Right Renal Artery

The crosstab and graph 4.21, show that abnormal peak systolic values of the right kidney are more common in both age groups, suggesting higher renal artery stenosis among young males. The minimum expected count of 6.70 ensures the results are reliable.

Crosstab

Count

		Peak Systolic Value Right Renal Artery		Total
		Normal	Abnormal	
Age	Age group 31-40	10	15	25
	Age group 20-30	6	12	18
Total		16	27	43

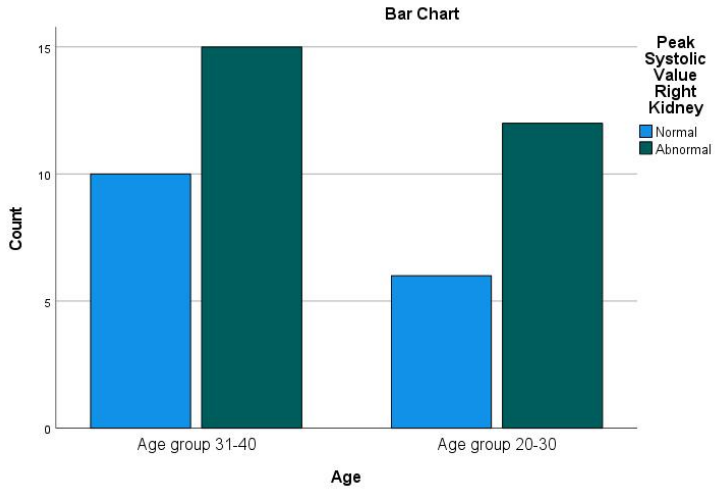


*Figure 4.21: Age * Peak Systolic Value Right Renal Artery*

Table 4.22: Age * Peak Systolic Value Left Renal Artery

The crosstab and graph 4.22, show that normal peak systolic values of the left kidney are more common in both age groups, while abnormal values are fewer. The minimum expected count is 6.70.

Crosstab

Count

		Peak Systolic Value Left Kidney		Total
		Normal	Abnormal	
Age	Age group 31-40	15	10	25
	Age group 20-30	12	6	18
Total		27	16	43

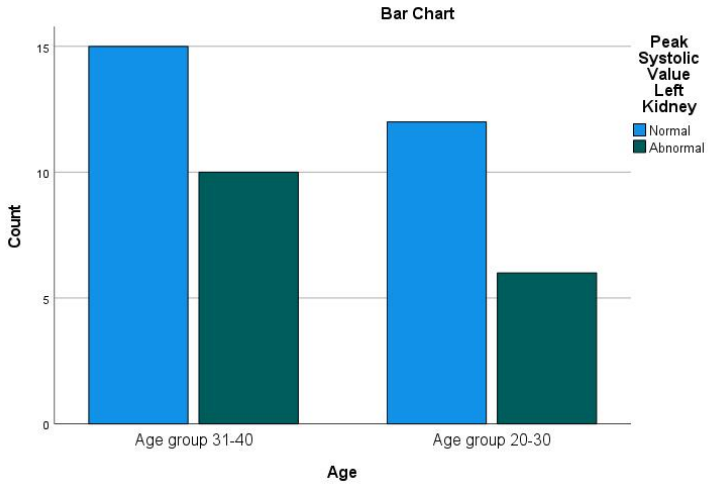


*Figure 4.22: Age * Peak Systolic Value Left Renal Artery*

Table 4.23: Age * Resistive Index Right Renal Artery

The crosstab and graph 4.23, show that abnormal resistive index values in the right kidney are more common across both age groups, indicating possible renal artery involvement in young males. The minimum expected count is 7.53.

Crosstab

Count

		Resistive Index Right Renal Artery		Total
		Normal	Abnormal	
Age	Age group 31-40	10	15	25
	Age group 20-30	8	10	18
Total		18	25	43

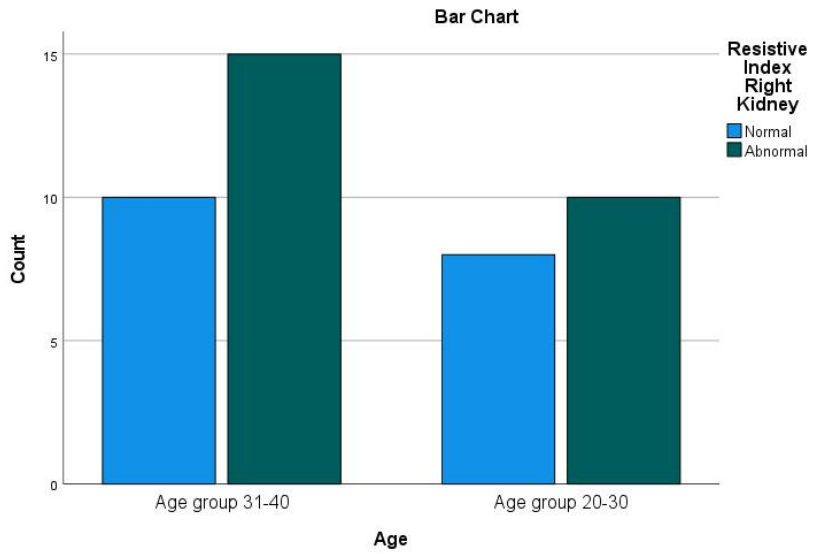


*Figure 4.23: Age * Resistive Index Right Renal Artery*

Table 4.24: Age * Resistive Index Left Renal Artery

The crosstab and graph 4.23, show that normal resistive index values in the left kidney are more frequent in both age groups, while abnormal values are less common. The minimum expected count is 6.70.

Crosstab

Count

		Resistive Index Left Kidney		Total
		Normal	Abnormal	
Age	Age group 31-40	15	10	25
	Age group 20-30	12	6	18
Total		27	16	43

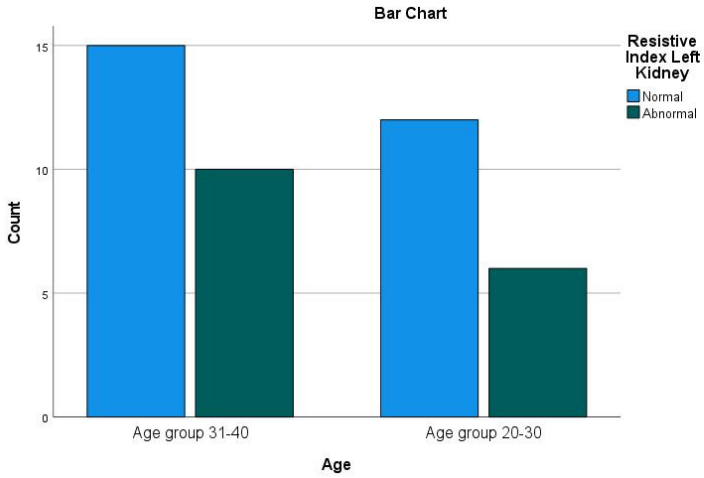


*Figure 4.24: Age * Resistive Index Left Renal Artery*

Table 4.25: Age * Renal Artery Ratio Right Renal Artery

The crosstab and graph 4.25, show that abnormal renal artery ratio values in the right kidney are more common across both age groups, suggesting significant renal artery involvement in young males. The minimum expected count is 6.70.

Crosstab

Count

		Renal Artery Ratio Right Renal Artery		Total
		Normal	Abnormal	
Age	Age group 31-40	10	15	25
	Age group 20-30	6	12	18
Total		16	27	43

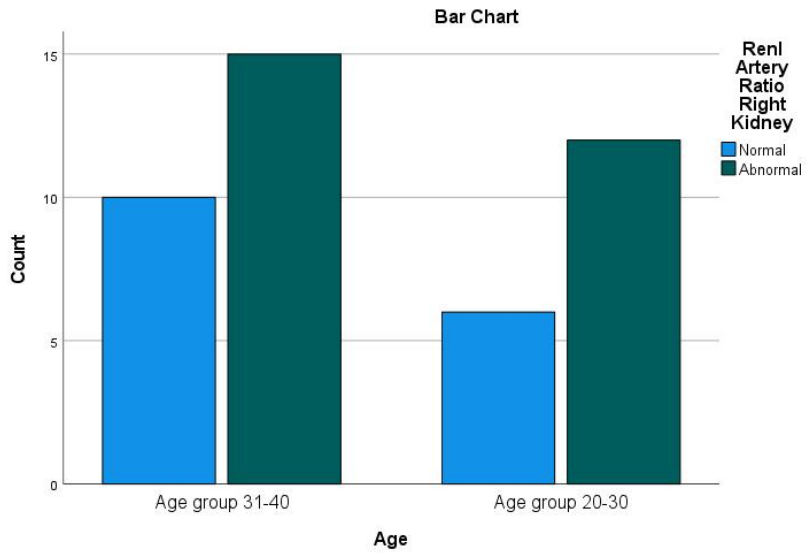


*Figure 4.25: Age * Renal Artery Ratio Right Renal Artery*

Table 4.26: Age * Renal Artery Ratio Left Renal Artery

The crosstab and graph 4.25, show that normal renal artery ratio values in the left kidney are more frequent in both age groups, while abnormal values are less common. The minimum expected count is 6.70.

Crosstab

Count

		Renal Artery Ratio Left Renal Artery		Total
		Normal	Abnormal	
Age	Age group 31-40	15	10	25
	Age group 20-30	12	6	18
Total		27	16	43

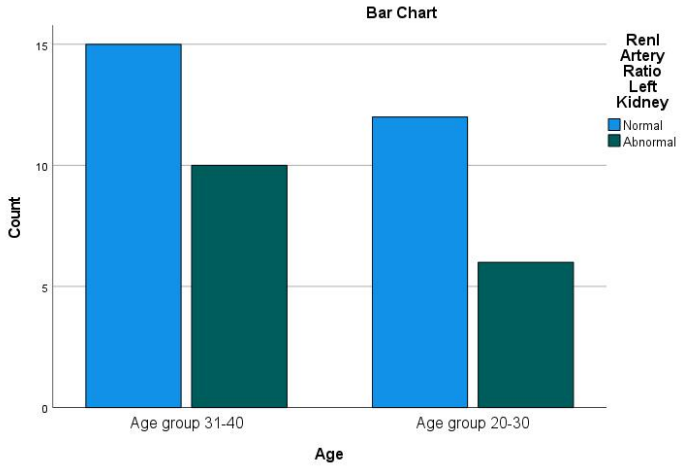


*Figure 4.26: Age * Renal Artery Ratio Left Renal Artery*

Table 4.27: Age * Mean Arterial Pressure

The crosstab and graph 4.26, show that all patients in both age groups had abnormal mean arterial pressure, indicating uncontrolled blood pressure across the study population. No statistics were computed since the values are constant for all cases.

Crosstab

Count

		Mean Arterial Pressure	Total
		Abnormal	
Age	Age group 31-40	25	25
	Age group 20-30	18	18
Total		43	43

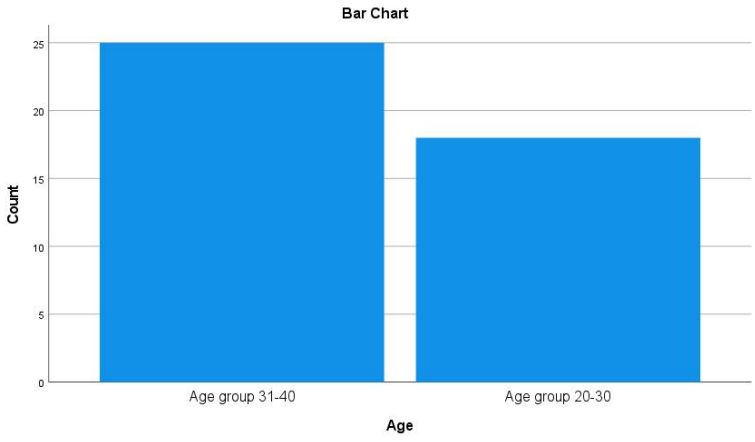


*Figure 4.27: Age * Mean Arterial Pressure*

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DISCUSSION

This study has determined renal artery stenosis (RAS), in young men with resistant hypertension, by the use of Doppler ultrasound (DUS). The argument deals with non-significant results, evaluates the expected and unexpected outcomes, combines the given results with the literature that already exists, and proposes the future research directions.

Resistant hypertension is increasingly becoming recognized in younger populations particularly among males where secondary causes such as RAS are more prevalent than ever before. The present research demonstrated that a high percentage of young men with resistant hypertension had abnormal Doppler parameters, i.e., high peak systolic velocity (PSV), high renal-aortic ratio (RAR), and abnormal resistive index (RI). The findings can be compared with previous research which indicates that renovascular disease especially in the younger patients is a significant cause of hypertension that is not responding to treatment.

The fact that abnormal Doppler results of the right renal artery were predominated in this study is consistent with prior research which identified a prevalence of unilateral RAS. Zierler (2017) and Davies et al. (2016) note that unilateral disease is also common and may still lead to serious systemic hypertension by the activation of renin-angiotensin-aldosterone system. More than 60% of the right renal arteries in this cohort had elevated PSV and RAR values, which support established diagnostic thresholds reported in the literature and indicate the presence of haemodynamically significant stenosis.

Despite adhering to antihypertensive medication, all participants showed consistently elevated systolic, diastolic, and mean arterial pressures, indicating true resistant hypertension. This result was anticipated since patients with uncontrolled blood pressure receiving the best possible medical treatment were the focus of the inclusion criteria. Comparable Calhoun et al. (2008) noted that resistant hypertension is closely linked to secondary aetiologies, especially renovascular disease.

Many patients had abnormal resistive index values, especially on the right side. RI is a measure of parenchymal compliance and intrarenal vascular resistance. Poorer renal outcomes and chronic ischaemic changes have been linked to elevated RI. It is important to note, though, that not every patient with abnormal RAR or PSV had elevated RI. This suggests that stenosis can be functionally relevant in some individuals as there is no essential parenchymal injury. This finding is in line with Meyer et al. (2019), who concluded that, especially in young patients, renal renovascular hypertension may precede the development of structural renal impairment.

The development of the renovascular alterations at an early age in young adults is demonstrated by the abnormal Doppler results in both groups (2030 and 3140 years old). The finding that patients as young as 20 years had important Doppler abnormalities presents the importance of early screening despite a more pronounced number of abnormalities observed in the 31 to 40 year group. These results are consistent with the study conducted by Gornik and Persu (2014), who revealed that RAS related to fibromuscular dysplasia often presents in young age and can remain undiagnosed over several years.

The observed lifestyle and clinical risk factors through this study also encourage the existing evidence. In the family history of hypertension, over 50 percent of the participants had a positive family history, which supports the impact of genetic factors on hypertension as was also reported by Whelton et al. (2018) and Martinez et al. (2022). Smoking was as well very common which can increase the endothelial dysfunction and expedite vascular pathology, even in the non-atherosclerotic disease. The presence of chronic kidney disease in more than a third of the participants would indicate that a subgroup of young patients already has their renal functioning being affected by long-term uncontrolled high blood pressure and renovascular disease.

Other results were not statistically discriminatory including homogenous abnormal blood pressure values and the universal report of symptoms like headache and dizziness. While subgroups were not differentiated by these results, they are still clinically relevant, since these results substantiate the symptoms load and disease severity of resistant hypertension. The lack of variability reflects the homogeneity of the study population rather than the absence of clinical significance.

Surprisingly, the involvement of the left renal arteries was not common as compared to the right side disease. This imbalance can be explained by anatomical or hemodynamic differences, variation in the sampling, or the small sample size. Also, the purposive sampling method and inclusion of patients with known RAS could also have affected the distribution of the findings. Although Doppler ultrasound proved to be very sensitive, it is also admitted that certain cases of stenosis could be underreported, which Vipparla et al. (2020) have also indicated, noting some false-negative DUS findings in certain patients.

The type of methodology employed in utilising Doppler ultrasound was appropriate based on the fact that it is non-invasive, it does not emit any ionizing radiation and can be practiced in limited resource settings. Despite the fact that angiography is considered the gold standard, several research findings have confirmed that DUS is an effective method of screening in the first line. Its current relevance is

supported in young males, where recurring imaging and extended follow-up might become a necessity.

To sum up, this research is aligned with the accumulating literature that Doppler ultrasound is an effective diagnostic tool that can be used to measure renal artery stenosis in young men with resistant hypertension. Renovascular disease can be detected early by DUS and timely intervention may be provided, thereby enhancing the management of blood pressure and decreasing cardiovascular and renal morbidity in the long term.

Further studies are necessary to address the research questions with bigger studies that include both sexes and a wider age of participants to enhance the generalizability. It is suggested that longitudinal studies would be necessary in order to determine how the disease develops over time and the effects of any intervention, say angioplasty or medical optimization. A comparison of results with CT or MR angiography would also support the use of Doppler ultrasound and establish better diagnostic guidelines.

CONCLUSION

This research pinpoints that renal artery involvement is of great prevalence in a group of young males with resistant hypertension. The majority of the participants had the age of 31-40 years, which indicates that even in the early adulthood, the renovascular causes of hypertension are prevalent. The Doppler ultrasound results were more prevalent of abnormal peak systolic velocity, resistive index and ratio of renal artery in the right kidney than in the left indicating that there was more renal artery stenosis in the right kidney than in the left kidney. The fact that all participants had continually high abnormal systolic, diastolic and mean arterial pressures when under medication was a true indication of resistant hypertension. The recurrent occurrence of the family history, smoking, headache, and dizziness further underline the multifactorial and intricate nature of hypertension among the group. All in all, Doppler ultrasound was a useful and non-invasive method of the identification of renovascular abnormalities in young patients with hypertension.

Limitations

The limitations of the study are a few and ought to be taken into account when interpreting the results. The sample size was quite small and restricted to young male patients hence limiting to generalizing the results to females and other age groups. The selection bias might be included because all participants were familiar with renal artery stenosis and it is difficult to measure the prevalence in a population of hypertensive patients. The cross-sectional design also makes it impossible to determine any cause

and effect of Doppler findings and resistant hypertension. Besides, no confirmation imaging methods (CT or MR angiography) were performed to compare the outcome with the Doppler ultrasound.

RECOMMENDATIONS

Doppler ultrasound is advised to be regularly used as the initial screening modal in young patients with resistant hypertension to detect potential renal artery stenosis at the earliest stage. In future research, the population size and gender should be greater and more varied to enhance the possibility of generalization. Longitudinal studies are also suggested to evaluate disease progression and treatment outcomes. Incorporating advanced imaging modalities alongside Doppler ultrasound would further strengthen diagnostic accuracy. Early identification and management of modifiable risk factors, particularly smoking and family history, are essential to reduce long-term cardiovascular and renal complications.

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