

Correlation of internal jugular vein, common carotid artery, femoral artery and femoral vein diameters with central venous pressure

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Abstract

Background: This study aimed to detect the correlation of central venous pressure (CVP) with the internal jugular vein (IJV), common carotid artery (CCA), femoral vein (FV), and femoral artery (FA) diameters measured with ultrasound (USG) in patients under mechanical ventilation to evaluate whether they are suitable to be used as an alternative low-cost and noninvasive method for the detection of CVP.

Methods: A total of 40 patients aged from 18 to 90 who had been receiving therapy in the intensive care unit (ICU) were included in the study. Central venous catheter was placed into the patients through right IJV or subclavian vein in their first 24-hour of hospitalization and the right atrium pressure (RAP) was measured from the catheter, the tip of which was confirmed to reach right atrium. In the same session, CCA, IJV, FA, and FV diameters were measured with USG and their correlations with CVP were calculated. In addition, correlations of the measured venous and artery diameters between each other were detected as well.

Results: There was a significantly high correlation between CVP and CCA diameter ($R = 0.603$, $P < .000$). There was a significantly low correlation between CVP and IJV diameter ($R = 0.352$, $P = .026$), a significantly low correlation between FA and FV diameters ($R = 0.317$, $P = .047$), a significantly low correlation between FA and CCA diameters ($R = 0.330$, $P = .038$), and a significantly low correlation between IJV and CCA diameters ($R = 0.364$, $P = .020$).

Conclusion: CVP and CCA diameters exhibited a high correlation. For detection of CVP, the ultrasonographic CCA diameter measurement can be used as an alternative noninvasive method which is easy to use and minimally affected by measurement errors of individuals and which has low learning curve compared with the other measurement methods.

Abbreviations: CCA = common carotid artery, CCAD = common carotid artery diameter, CVP = central venous pressure, FA = femoral artery, FAD = femoral artery diameter, FV = femoral vein, FVD = femoral vein diameter, ICU = intensive care unit, IJV = internal jugular vein, IJVD = internal jugular vein diameter, IVC = inferior vena cava, IVCCI = inferior vena cava collapsibility index, IVV = intravascular volume, PEEP = positive end-expiratory pressure, RAP = right atrium pressure, USG = ultrasound.

Keywords: central venous pressure, diameter measurement, health expenditures, intravascular volume

1. Introduction

Resources' smart allocation is an important issue in health economics and thus is an issue that health system administrators and public health specialists should focus on.^[1] Since it has been reported that the percentage of patients who need to be admitted to intensive care, in general, has increased over the years,^[2] intensive care unit (ICU) expenditures have also gained importance in terms of paying more attention to the effective use of limited health resources.

Every patient in ICUs should receive hemodynamic monitoring. Patient monitoring capabilities developed a lot and became complex increasingly along with the developments in technology and critical care medicine. Technologically

complex monitoring almost always means a rather expensive pathway of monitoring. It might be better to consider noninvasive monitoring methods to cut of expenditures when possible.^[3,4]

Detection of intravascular volume (IVV) status, fluid infusion if this volume was under a certain threshold, and elevation of cardiac output due to that depends on the place of the heart on the Frank-Starling curve. According to the Frank-Starling curve, preload of the heart decreases when IVV falls under a certain threshold (in the vertical part of the curve), cardiac output decreases, and tissue oxygenation is impaired as a result of the decrease in tissue perfusion. Similarly, fluid overload in the body leads to cardiac dysfunction and overload findings and increases mortality according to the

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Frank-Starling curve.^[5] Therefore, bedside assessment of IVV status especially in ICU patients is used as an important part of patient management.^[6]

Dynamic parameters such as echocardiographic measurements of end ventricular volumes and inferior vena cava collapsibility index (IVCCI), inferior vena cava distensibility index, measurement with transpulmonary thermodilution method, and passive leg raising test are used for prediction of cardiac preload as well as static parameters such as the measurement of central venous pressure (CVP) and pulmonary artery occlusion pressure.^[7] Moreover, the search for less invasive and more practical methods with a lower learning curve and possible to use in all patient groups continues as well. Therefore, it is considered that internal jugular or femoral vein (FV) collapsibility indices and internal jugular vein (IJV) and carotid artery cross-sectional area measurements can be used in the prediction of IVV as well.^[8]

In recent years, ultrasonographic measurements that are less invasive methods in the detection of IVV status have started to come into prominence.^[9] Therefore, the determination of inferior vena cava (IVC) diameters and IVCCI has been associated with IVV status and clinical response to clinical interventions^[10]; however, it is difficult to use this modality in patients with abdominal surgery, abdominal injuries, morbid obesity and increased intra-abdominal pressure, abdominal distension, intestinal gas distension, and excessive tissue edema. In addition, the measurement requires a more advanced technique and needs a special ultrasound (USG) probe, which are the limitative factors.^[8,11,12]

Although several different methods are described the measurement of right atrial pressure through a central venous catheter is still used as a valuable method in the prediction of fluid volume in conditions fluid load is needed.^[13] However, there are annoying complications associated with a CVP catheter, the tip of which is inserted into the right atrium to measure CVP and which gives the opportunity for static measurement. Pneumothorax, bleeding and arterial punctures, local and remote infection risks such as insertion site infections and blood circulation infection associated with catheters, and septic emboli are among these complications.^[11]

There are also studies asserting that IJV to common carotid artery (CCA) ratio measurement by using USG is effective for prediction of CVP in case common measurement methods cannot be used.^[14,15] It is possible to obtain named artery and vein diameters using an easy ultrasonographic measurement with a low learning curve and a low possibility to get affected by multiple factors, non-invasively, and less costly.

This study aimed to discuss whether it is possible or not to use the diameters of the IJV, CCA, and femoral artery (FA), FV in the prediction of CVP as alternatives to left atrium pressure values obtained through central venous catheterization, via determining and assessing the correlation amongst these values.

2. Methods

2.1. Patient selection

A total of 40 patients who had been receiving therapy in the ICU were included in the study after the approval (Number: 2020/39) of the Omer Halisdemir University Ethics committee. The whole study was performed in accordance with the principles of the Helsinki Declaration. The inclusion criteria for the study were as follows: Staying at ICU, being between the ages of 18-90, receiving assisted invasive mechanical ventilation, having a Ramsey sedation scale score over 6, and whether the patient had fluid deficit or not was not known, having received central venous catheterization through IJV or subclavian vein during a stage of the treatment process for follow-up of hemodynamic condition, and being connected to mechanical ventilation.

Patients with severe cardiac disorders (cardiac pathology, pulmonary hypertension), those with intra-abdominal pressure >12 mm Hg, obese patients (body mass index > 35), patients with traumatic injury, patients in whom any of IJV, CCA, FV, or FA could not be monitored with USG, patients with systolic blood pressure under 90 mm/hg despite noradrenaline infusion above 1 µg/kg/min, patients with a body temperature above 37.5°C, and patients with “Acute Physiology and Chronic Health Evaluation” II scores above 35 were excluded from the study.

2.2. Clinical data

The measurements were performed within the 24-hour period after the right jugular or subclavian venous catheter was inserted after central venous catheter indication occurred during the routine treatment process of patients. After the central venous catheterization, whether the central catheter tip was inside the right atrium or in the entry of the right atrium was confirmed with chest radiography. While the CVP was being measured the patient's spine was in a neutral position and while the bedhead of the patient on spine position was elevated to 30° CVP monitoring was performed with Mindray BSM9101K monitor and all fluid infusion from the central catheter was stopped. Then, the transducer or amplifier was reset to atmospheric pressure and then, the transducer was lined up with the horizontal plane of the tricuspid valve, and the pressure value on the monitor was recorded as mm Hg.

The procedure continued with CVP measurement and right IJV, CCA, FV, and FA diameter measurements of the patients with USG in the same session (Fig. 1). Sonographic assessments were performed using a Mindray Dp-50 portable USG device (Shenzhen P.R China) with a 7.5-MHz linear probe as described by Bailey et al before.^[16] The patients were placed in spine position while they were horizontally on bed level without a pillow or any other objects under their heads. The highest diameters and cross-sectional areas of IJV and CCA from the lowest level of the thyroid cartilage and the highest diameters and cross-sectional areas of FV and FA from the level just under the inguinal ligament were measured on the horizontal and vertical axis and the obtained values were averaged. IJV and CCA measurements were separately performed during inspiration and expiration and the measured values were averaged. FV and FA diameter measurements were performed as a single measurement and averaged.

2.3. Statistical analysis

As a result of the G-Power analysis performed based on the data obtained from the correlation between CCA and CVP in the study by Sherer B. et al, the calculation is done with 0.95 power, 0.5 effect size and 0.05 type1 error revealed that a sample size of 34 patients was required.^[15]

SPSS 22.0 (IBM Corp. Armonk, NY) was used for statistical analyses. The quantitative variables were presented as mean ± standard deviation and categorical variables as numbers (percentile). Shapiro–Wilk and Kolmogorov-Smirnov tests were used to assess the normality of distribution for quantitative variables. Pearson's or Spearman's correlation analysis was used to assess the correlation between CVP and IJV, CCA, FV, and FA. It was determined according to Pearson's correlation coefficient (r) value. The interpretation of Pearson's correlation coefficient (r) value: $R < 0.2$ was interpreted as very weak correlation or no correlation, R value between 0.2 and 0.4 as weak correlation, R value between 0.4 and 0.6 as moderate correlation, R value between 0.6 and 0.8 as high correlation, and $R > 0.8$ as very high correlation. The statistical significance value was determined as $P < .05$ for all tests.

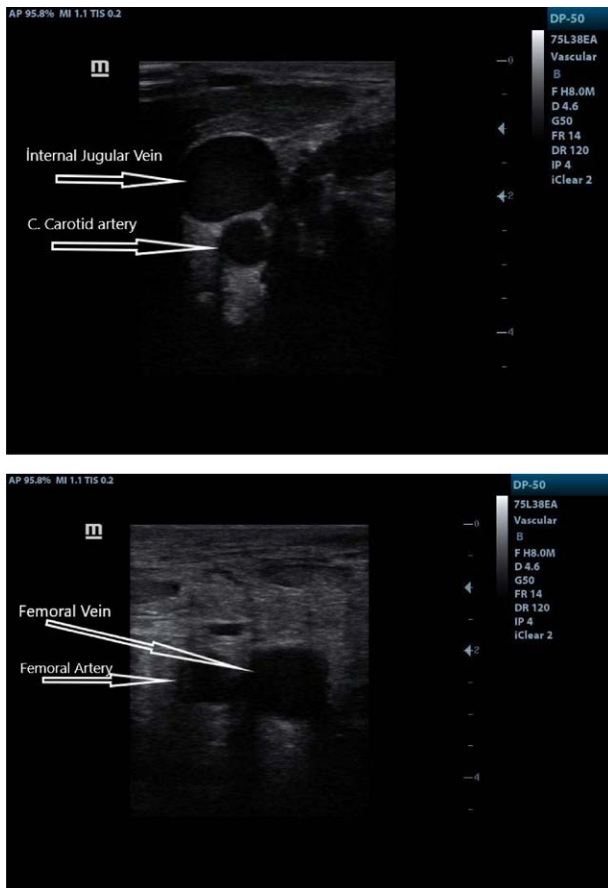


Figure 1. CCA, IJV, FA, FV ultrasonographic images. CCA = common carotid artery, IJV = internal jugular vein, FA = femoral artery, FV = femoral vein.

3. Results

Of the patients included in the study, 17 were female and 23 were male. The mean age was 60.03 years. When the diameters of the CCA, FA, FV, and IJV are measured (Fig. 2), as a result of the measurements, mean CVP was measured as 7.23 (0-14) mm Hg, mean femoral artery diameter (FAD) as 0.79 (0.47-1.54) cm, mean femoral vein diameter (FVD) as 1.04 (0.7-1.62) cm,

mean internal jugular vein diameter (IJVD) as 1.21 (0.55-2.02) cm, and common carotid artery diameter (CCAD) as 0.79 (0.43-1.20) cm (Table 1).

The correlation between the CVP and the diameters of the great vessels was measured (Fig. 3). As a result of the measurements, there was a non-significantly weak correlation between CVP and FAD ($R = 0.236, P = .142$). There was a non-significantly very weak correlation between CVP and FVD ($R = 0.128, P = .433$) and a significantly weak correlation between CVP and IJVD ($R = 0.352, P = .026$). There was a significantly high correlation between CVP and CCAD ($R = 0.603, P < .001$). There was a significantly low correlation between FAD and FVD ($R = 0.317, P = .047$) and a significantly weak correlation between FAD and CCAD ($R = 0.330, P = .038$). While there was a significantly low correlation between IJVD and CCAD ($R = 0.364, P = .020$) there was a non-significantly very low correlation between IJVD and FVD ($R = 0.140, P = .390$) (Table 2).

4. Discussion

The right atrium pressure (RAP) is an important compound in the assessment of hemodynamic conditions of patients and the most important measurement used in the close-to-correct prediction of pulmonary artery pressures. RAP provides a prediction of IVV which is a critical compound for optimal patient care and management. The increasing RAP is associated with negative results and mortality independently caused by all reasons in patients with a cardiovascular disorder. The RAPs can also be measured with noninvasive methods such as indices obtained from vena cava inferior, systemic and hepatic veins, Doppler US, and right atrial diameter measurement; however, the gold standard for the most correct measurement is the one performed with a pressure catheter inserted into the atrium.^[17]

The CVP can be used in the prediction of pre-load and right atrial pressure. The CVP is measured using a central venous catheter which is carried forward through the IJV and inserted into the superior vena cava which is next to the right atrium. Normal CVP is between 8 and 12 mm Hg. This value is altered by volume status and/or compliance.^[18]

On the other hand, the new pieces of evidence reveal that there is no absolute direct correlation between CVP and total blood volume in circulation. Although it is asserted that CVP is a weak predictor of fluid response with the emergence of the

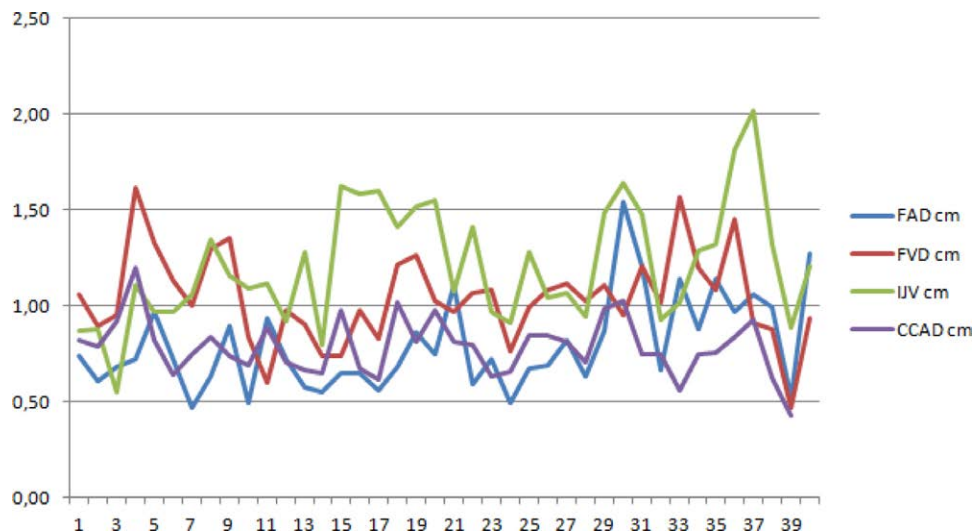


Figure 2. IJVD, CCAD, FAD, and FVD measurements. CCAD = common carotid artery diameter, FAD = femoral artery diameter, FVD = femoral vein diameter, IJVD = internal jugular vein diameter.

Table 1
Demographic data.

Variable	Mean	Standard deviation	Minimum - maximum
Age	60.23	19.75	18 - 98
Weight	77.05	10.35	55 - 105
CVP	7.23	3.75	0 - 14
FAD	0.79	0.24	0.47 - 1.54
FVD	1.04	0.23	0.7 - 1.62
IJVD	1.21	0.31	0.55 - 2.02
CCAD	0.79	0.15	0.43 - 1.20

CCAD = common carotid artery diameter, CVP = central venous pressure, FAD = femoral artery diameter, FVD = femoral vein diameter, IJVD = internal jugular vein diameter.

concept of “fluid responsiveness” and its effect on the patient result several young clinicians keep using the CVP, especially in the management of cardiovascular cases.^[19]

The CVP declines depending on hypovolemia or reduced venous return in venodilation and the increased CVP can occur in heart failure due to reduced cardiac contractility, valve abnormalities, and arrhythmias.^[20] High CVP is also the indicator of myocardial contractile dysfunction and/or fluid retention. Due to all reasons, the CVP is still used especially for the assessment of cardiac function despite its numerous limitations.^[21]

For a more accurate assessment of the volume status, an easy-to-determine CVP in addition to indices such as the IVCCI can still be clinically an appealing indicator although the fluid

status is not specific.^[22] Therefore, we considered in our study that other easier-to-measure vein diameter measurements could also be used in the prediction of RAP.

Hooman Hossein et al assert that the IJV to CCA ratio ($R = 0.732, P = .001$) can be a noninvasive scale to assess hemodynamic status in patients who do not receive mechanical ventilation. In our study, IJV to CCA ratio ($R = 0.364, P = .020$) was significant as well and there was a weaker but significant correlation between both measurements. The most important difference between the 2 studies is that our study was performed on patients under mechanical ventilation.

M. Aslan et al^[23] investigated the correlation between IVCCI and CVP in their study on patients under mechanical ventilation and found a correlation between the 2 measurements ($R = 0.412, P = .020$). In our study, we investigated whether this correlation was between CVP and central vein diameters that are more easily measured and we preferred measuring vein diameters instead of collapsibility index.

Sheher B et al found a correlation both in inspiration and expiration in their study in which they investigated the correlation between CVP and IJV/CCA ($R = 0.419$). In our study, we separately measured CCA and IJV in inspiration and expiration and used the average of these values. This result is consistent with the results of our study ($R = 0.364$). In the same study, a weak correlation was found between CVP and CCA, but this value was not statistically significant ($R = 0.281, P = .05$). In our study, there was a strong correlation between CVP and CCA ($R = 0.603, P < .001$). We think this increase in the correlation may be because our patients were under mechanical ventilation.

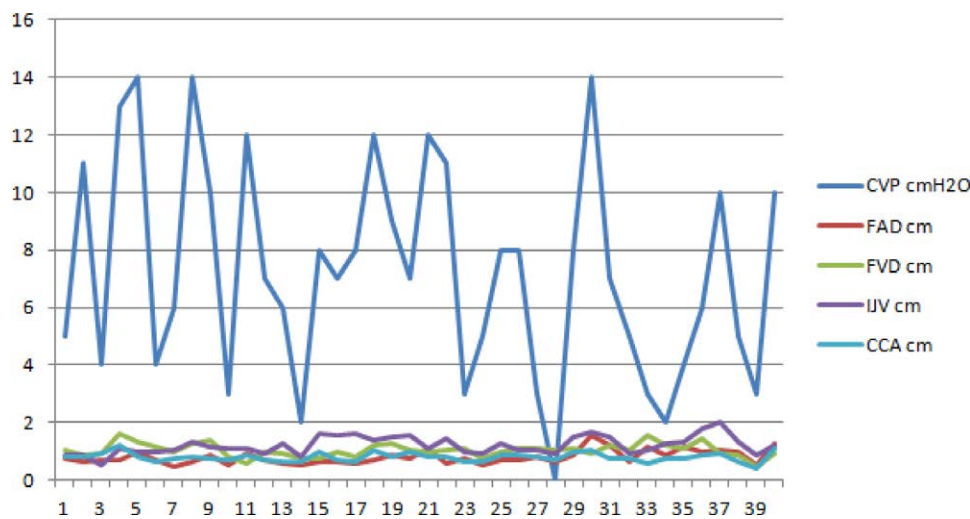


Figure 3. The correlation between central venous pressure and diameters of large veins.

Table 2
Correlation analysis.

Correlation	r-value	P value
CVP and FAD	0.236	.142
CVP and FVD	0.128	.433
CVP and IJVD	0.352	.026
CVP and CCAD	0.603	.000
FAD and FVD	0.317	.047
FAD and CCAD	0.330	.038
IJVD and CCAD	0.364	.021
IJVD and FVD	0.140	.390

CCAD = common carotid artery diameter, FAD = femoral artery diameter, FVD = femoral vein diameter, IJVD = internal jugular vein diameter.

Girijapati et al^[24] measured the effect of positive end-expiratory pressure (PEEP) value on IJV diameter in patients who were under mechanical ventilation and who received anesthesia for surgery in their study and found that the increase in PEEP caused an increase in IJV diameter. In our study, the PEEP values of the patients were under about 5 to 10. IJV diameters measured in our patients were higher than the values in that study. The reason may be that patients included in our study were ICU patients with higher comorbidity.

There are also studies revealing that the increase in fluid volumes and increase in blood flow rates increase the CCA diameter as well as studies assessing the correlation between IJV and CCA. N Sasaki et al^[25] asserted that CCA parameters assessed with USG can help determine the individuals carrying high hypertension risk. Kozaburo H et al^[26] found that the increase

in blood flow rate caused reformation in the wall of the artery and thereby caused an increase in CCA diameter.

Samaa A et al^[27] found a significant and strong positive correlation ($R = 0.8$, $P < .001$) between CVP and CCA diameter before fluid infusion and a moderate positive correlation between the increase in CVP and increase in CCA diameter after fluid infusion ($R = 0.4$, $P < .001$) in their study on 65 patients who received anesthesia for major surgery. The percentage of the increase in CCA diameters revealed a positive correlation with the increase in CVP following the fluid infusion ($R = 0.589$, $P = .001$). In our study, we found a significantly high correlation between CVP and CCAD ($R = 0.603$, $P = .000$). Our results were quite similar to the results of Samaa et al.

Marik et al^[28] reported in their study on 34 patients, 19 of whom were under mechanical ventilation, that there was a strong correlation between the change in carotid blood flow and percentage change in stroke volume index in patients in whom more than 10% increase was observed in stroke volume index after passive leg raising test. The high correlation between RAP measured through CVP and CCA diameter in our study supports the result of Marik et al

We also assessed the correlation of CVP with FA and vein diameters that can be relatively easily measured with the ultrasonographic method. There was a weak correlation between CCA and FA ($R = 0.330$, $P = .038$), which made us consider that there may also be a correlation between large arteries. Apart from that, we could not detect the correlation of FA and vein diameters with CVP.

The limitations arising from the technique used in our study and study design are as follows: First, while assessing CCAD and IJVD, both end-inspiratory and end-expiratory measurements were made and averaged. This is a fairly short period of time and imaging during this time is a relatively difficult process. Second, in order to standardize measurements, positioning all patients supine and horizontally at bed level, with no pillows or other objects under their heads is necessary. Third, a portable bedside USG device is needed to measure all patients' vessel diameters. Fourth, our study involves only the intensive care patients receiving mechanical ventilation thus the results should be tried in different clinical environments and patients as well. Fifth, although our reference method is the assessment of a catheter inserted into the right atrium of CVP the measurement itself can have minor errors. However, these kinds of measurement errors are mostly randomly distributed and the possibility of finding significant correlations is low.

It should also be considered that large vessel diameters are affected by various factors. There are vasodilator factors such as nitric oxide (NO), prostacyclin (PGI₂), and endothelium-derived hyperpolarizing factor (EDHF), which are vasoactive factors released from the vascular endothelium, or vasoconstrictive factors such as thromboxane (TXA₂) and endothelin-1 (ET-1). The balance between these factors can be decisive in vessel diameters.^[29] In our study, we did not consider the effect of vasoactive factors that change vessel diameters.

5. Conclusion

CVP exhibits a high correlation with CCA diameters. Since economical assessments became an important part of policy decisions on the use of healthcare technologies^[30]; the ultrasonographic CCA diameter measurement can be used as an alternative noninvasive method for the detection of CVP. Although it is easy to use and minimally affected by measurement errors of individuals and has a low learning curve compared with the other measurement methods, further studies are needed to confirm our results.

Author contributions

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Investigation: Muhammet Bayraktar, Mustafa Kaçmaz.

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Writing – original draft: Muhammet Bayraktar, Mustafa Kaçmaz.

Writing – review & editing: Muhammet Bayraktar, Mustafa Kaçmaz.

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