Numerous methods of noninvasively measuring cardiac output (CO) have been developed, but although these techniques have been used well to manage patients with cardiovascular diseases, their accuracy in patients with pulmonary hypertension (PH) has not been extensively investigated. An assessment of CO is very important in PH patients, because the severity of right ventricular dysfunction is a strong determinant of poor prognosis in these patients. In particular, the hemodynamic status of patients with severe PH is often unstable and requires frequent monitoring. In recent guidelines, hemodynamic monitoring is recommended to be repeated either immediately after worsening of the clinical state or 3–6 months after the induction of a new treatment. Therefore, reliable tools are needed to assess cardiac function. Although Doppler echocardiography is a noninvasive method that is frequently used to evaluate CO, the Doppler-derived CO is partly inaccurate in PH patients, probably because of the dependency on operator technique and the patient’s enlarged heart geometry. In addition, echocardiography is not a monitoring device. Right heart catheterization (RHC) is a direct measurement of hemodynamic parameters and is a reliable tool for evaluating hemodynamic changes in PH patients. However, the frequent use of RHC is also limited by its invasiveness, infection risk, and expense. Therefore, a noninvasive technique for monitoring CO is needed to help manage PH patients. This editorial provides an overview of the major methods for measuring CO, and discusses the usefulness of noninvasive CO measurement in patients with PH.

Conventional Measurement of CO

In the 1890s, Adolph Fick presented the first method of estimating CO, which involved determining the relationship between the rate of oxygen uptake in an organ and the difference in oxygen saturation between arterial and venous blood. Since then, many methods have been developed to measure CO noninvasively. Among these, the most widely used method is catheterization, which involves placing a catheter into the right heart and measuring the pressure changes that occur when blood is pumped through the heart. This technique provides direct measurements of hemodynamic parameters and is considered the gold standard for assessing CO. However, catheterization is invasive and carries the risk of infection and other complications.

Noninvasive Measurement of CO

Recently, noninvasive methods for measuring CO have become available. These methods include echocardiography, which uses ultrasound to calculate CO, and various forms of electrical impedance cardiography (EICG). EICG measures CO by recording changes in the electrical impedance of the body, which is related to the volume of blood flowing through the heart. This method is noninvasive and does not require any special training to perform.

Conclusion

In conclusion, CO is an important parameter for assessing the hemodynamic status of patients with PH. While invasive methods such as RHC provide accurate measurements, noninvasive methods such as EICG offer a more convenient and less invasive alternative. Further research is needed to develop more accurate and reliable noninvasive methods for measuring CO in PH patients.
gen concentration. The Fick formula is as follows: CO = oxygen consumption/arteriovenous oxygen difference. To calculate the Fick-derived CO, arterial and mixed venous oxygen concentrations and oxygen consumption are inversely sampled using a pulmonary artery catheter. Although this technique has been modified to be a noninvasive method using re-breathing carbon dioxide, the accuracy of indirect Fick-derived CO in PH patients remains questionable. In the 1940s, Hamilton developed a method that uses a dilution technique, referred to as the thermodilution method, which determines the CO from the serial change in the temperature of an indicator, such as iced glucose, injected from the right atrium. Thermodilution-derived CO remains reliable in patients without a cardiac shunt, but the disadvantages of this method are its invasiveness and the inability to collect serial measurements. In 1994, Erlanger et al reported their serial measurement of CO based on arterial pressure pulse. This pulse contour method determines the CO from the arterial pulse wave through an intra-arterial catheter in the radial artery. Although several minimally invasive techniques using pulse contour have become available to continuously measure CO, the usefulness of these methods in patients with PH has never been tested.

Noninvasive Measurement of CO in PH Using Impedance Cardiography (ICG)

ICG is a plethysmographic technique of estimating CO. The thoracic method (ICGtr) applies a high-frequency electric current of known amplitude and frequency across the thorax from electrodes placed on the root of the neck and on the lower chest. Numerous studies have demonstrated the accuracy of ICGtr-derived CO in healthy volunteers. In patients with moderate PH, the ICGtr-derived CO has been reported to show a good correlation with RHC-derived CO. In this issue of the Journal, Taniguchi et al report that a noninvasive cardiac system (NICAŠ: NI Medical, Hod-Hasharon, Israel) is an accurate tool for noninvasively and serially measuring CO in patients with moderate PH. This system noninvasively determines CO based on another ICG method, whole-body impedance cardiography (ICGwb), which involves electrodes placed on 1 wrist and on the contralateral ankle (Figure). The study demonstrated that NICAŠ-derived CO determinations correlate well with thermodilution- and Fick-derived CO measurements.

Is ICG Useful in Patients With Severe PH?

Although ICG seems to be reliable for the noninvasive measurement of CO in patients with PH, there remains a specific issue with these measurements that must be considered. Two studies have demonstrated the accuracy of ICG-derived CO in patients with moderate PH, but it remains to be demonstrated whether the technique is reliable in patients with severe PH, who require frequent monitoring. Generally, the major disadvantage of ICG is the electric noise caused by various physiological factors, such as peripheral edema, lung fluid, body motion, temperature and humidity, which may alter the electric conductivity. In fact, there was a poor correlation between ICG- and RHC-derived CO in patients with congestive heart failure, whereas there was good correlation in patients with non-congestive heart failure. These results suggest that the accuracy of ICG-based CO measurements in patients with some physiological factors, including peripheral edema and pulmonary congestion, might be questionable. In the study reported by Taniguchi et al, most of the enrolled patients showed normal CO levels by RHC analyses. Thus, the accuracy of ICG-derived CO in patients with severe PH has not been well investigated. To confirm the usefulness of the ICG technique for measuring CO in PH patients, its reliability in patients with severe PH must be definitively demonstrated.

In conclusion, a technique for the noninvasive measurement of CO is needed to manage patients with PH. The study reported by Taniguchi et al demonstrated that whole-body ICG may provide reliable CO data in patients with moderate PH. However, a large study is still needed to investigate the accuracy of this method in severe PH patients, who require frequent monitoring.

References