Catheter Vessel Ratio: Now What?

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WHAT IS THE EVIDENCE?

Catheter-related thrombosis (CRT) poses a serious, yet challenging situation for clinical providers working within today's current healthcare environment. The clinical issues generated by this phenomenon are problematic and often lasting well beyond the initial diagnosis and potential treatment protocols.

Upper extremity-deep vein thrombosis (UE-DVT) refers to the formation of a thrombus within the deep vessels of the upper arm and chest: primarily the subclavian, axillary and brachiocephalic veins, but also the basilic, brachial, and the more increasingly, superficial cephalic veins, in the arm.

An early retrospective venography study (Allen et al, 2000) described high thrombosis rates with 23.3% of patients developing thrombosis after the initial PICC placement (overall thrombosis rate 38%), yet did not encompass vessel size as a potential influencing factor, citing age, sex, cannulated vein, catheter size, location, and incidence of thrombosis risks. Whilst there have been more recent considerations regarding catheter to vessel ratios (Sharp et al, 2013; Sharp et al, 2015; Sharp et al 2016), there is still limited evidence in its role of thrombosis reduction strategies in vascular access practices.

Much focus on this phenomenon has targeted the increased use of peripherally inserted central catheters (PICCs) in the last two decades (Elman and Khan, 2006; King et al, 2006; Evans et al, 2010; Cotogni and Pittiruti, 2014; Chopra et al, 2015; Greene et al, 2015; Holder et al, 2017) especially with its increasing demand for non-physician facilitated insertions (Alexandrou et al, 2010, Ramirez et al, 2010; Johnson et al, 2015).

Although there has been a strong focus on larger diameter PICCs and thrombosis risk (Trerotola et al, 2010; Chopra et al, 2012), there has been insufficient information established on what relationship to vessel size is appropriate for a device-specific external diameter. Early references to clinical standards and published guidelines did not clearly address appropriateness of vessel size in relation to external catheter diameter.
Virchow's Triad:
This pathophysiological explanation describes the precursors around three core relationship development of vascular thrombosis. The triad consists of the following components: vessel wall damage or endothelial injury, alterations in blood flow (hematological stasis), and hypercoagulability of the blood, deeming it a significant effector in prevention of vessel- and catheter-related complications.

Vessel Health & Preservation:
Directs the clinician through a closer assessment of the patient and uses tools to ensure a thorough vascular assessment and review of the overall patient treatment plan. VHP encompasses current clinical guidelines and evidence-based literature, in doing so, creating a programme that comprehensively addresses the issues of education, assessment, placement, and daily assessment of patient condition to determine device necessity. VHP represents the pinnacle of evidence-based knowledge development as a risk reduction strategy that complies with many professional organizations;

- The Joint Commission (TJC)
- Oncology Nurses Society (ONS)
- Infusion Nursing Society (INS)
- Association for Vascular Access (AVA)
- Agency for Healthcare Research and Quality (AHRQ)
- Centers for Disease Control (CDC)
- Registered Nurses Association of Ontario (RNAO)
- Association for Professionals in Infection Control and Epidemiology, (APIC)
- The Society for Healthcare Epidemiology of America (SHEA)
- Institute for Healthcare Improvement (IHI)
Catheter Vessel Ratio (CVR):
To a large extent, it comes down to annular mathematical proportions and is measureable by well-trained clinicians with ultrasound (US). However, this process is often forgotten as part of the vascular assessment process when devices are placed for intravascular therapies. A relatively simple issue, but nonetheless, a very important one which can have significant effect on the functioning of the device, as well as blood flow characteristics within the vessel.
**IMPORTANCE OF CVR**

Implications

Catheter-related thrombosis (CRT) has serious implications related to the loss of vascular access, development of pulmonary embolism (PE), recurrent VTE, infections and post-thrombotic syndrome. The pathogenesis of CRT is complex and multifactorial, with risk factors associated with the catheter, the vessel selected for insertion and the underlying patient co-morbidities and their treatments. The monitoring of the catheter to vessel ratio (CVR), whereby vessel and catheter size are measured for relationship appropriateness, may have potential influence on CRT, by potentially reducing venous stasis and improving flow dynamics around the body of the catheter.

There is now established clinical evidence that shows CRT is related to the catheter size within the intraluminal space (Trerotola et al, 2010; Chopra et al, 2012; Evans et al, 2013) and the literature regarding these adverse events emanates from 2 distinct patient populations: those with and without cancer. And as anticipated, venous thromboembolism (VTE) estimates in patients with cancer and critically ill patients consistently exceed those of patients without cancer or ICU level of care (Chopra et al, 2012).

How to define the CVR

Nifong and McDevitt (2011) state the presence of a catheter within the lumen of a vein will “decrease blood flow and potentially create venous stasis, and that the size of the catheter versus the vein has significant impact, particularly with peripherally inserted central catheters (PICCs)”. The understanding that catheter size may potentially influence venous stasis within the vessel and exacerbate venous thrombosis had not been scientifically explored before, and although is now gaining more attention, there is still no clear process to facilitate proper clinical standards about vessel and catheter sizes.

We have defined the Catheter to Vessel Ratio (CVR) as the

“**indwelling space or area consumed or occupied by an intravascular device inserted and positioned within a venous or arterial blood vessel.**”
Although a broad literature search was performed, no identifiable evidence was returned regarding the “rule of thumb” often inherently followed by many practicing vascular access clinicians when inserting intravascular devices, or that the ‘default’ 33% catheter vessel ratio was referenced as a standard of clinical practice.

A review of the INS Standards of Practice (SOP) from both 2006 and 2011 did not specify a recommended vessel size or measurement to set an upper limit of diameter for a vascular device to be placed.

The 2016 INS SOP however did include more recent evidence to say that a catheter vessel ratio of <45% was a satisfactory risk prevention strategy. The publication by Sharp et al, (2015) showed that there was statistical significance with catheter vessel ratios >45%, with a 13-fold increase in CRT risk.

We compared the traditional ‘rule of thumb’ (or 33%), and the recent 45% rule of catheter to vessel ratios. However, these general rules are based on a two-dimensional measurement, not focusing on the area the catheter takes up within the vessel, which is a three dimensional perspective.

$r_{cath}$ - radius of catheter

$r_{vess}$ - radius of vessel

$ecc$ - distance between catheter and vessel center
We have designed a preliminary tool using a mathematical-based formula to determine consumed area by a potential intravascular device. This will help clinicians with decision making in the appropriateness of a catheter to vessel ratio of 45% or less.
INTRODUCTION OF THE TOOL

The Catheter Vessel Ratio Tool

Understanding the tool.

The example below demonstrates a 5 French catheter showing the relationship of vessel size and area consumed by the catheter.

**RED ZONE** - 45% or greater - high risk zone

**YELLOW ZONE** - 34-44% - cautionary zone

**GREEN ZONE** - 33% or less - safe zone

Using this conversion process the authors could determine the areas where catheter and vessel sizes were within the 3 zones.
How to use the tool.

Here is an working example of how to determine the CVR for a measured vessel (4.2mm) and a 5Fr catheter.

1. Assess the vessel with US to obtain vessel size

![Vascular Access Image]

2. Refer to the tool and find the closest size along the top row

3. Slide your finger down to find the corresponding catheter size you wish to insert

![Catheter Size Table]

4. What color do you see at the intersection?

Behind the scenes mathematics..

<table>
<thead>
<tr>
<th>Catheter Size (Fr)</th>
<th>Catheter OD (mm)</th>
<th>Radius of Catheter (mm)</th>
<th>Area of Catheter (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5F</td>
<td>1.65</td>
<td>0.83</td>
<td>2.14</td>
</tr>
<tr>
<td>Vessel OD (mm)</td>
<td>Radius of Vessel (mm)</td>
<td>Area of Vessel (mm²)</td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>2.10</td>
<td>13.85</td>
<td>CVR 15.43%</td>
</tr>
</tbody>
</table>
DISCLOSURES

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ABSTRACT

Background: Throughout the practice of vascular access, catheter to vessel ratio has been used by clinicians to help select the most appropriate device for the insertion vessel. In 2016, the INS Standards of Practice set a recommendation that the catheter to vessel ratio can increase from 33% and now take up to 45% or less of the vessel diameter.

Purpose: To standardize the process of vessel assessment, incorporating catheter to vessel ratio, vessel health and preservation, and Virchow’s triad, empowering an evidence-based approach to device placement.

Project: Definitions will be provided to help the clinician have the basic understanding of the concepts of catheter to vessel ratio, vessel health and preservation and Virchow’s triad. This will conceptualize and illustrate the differences of the two-dimensional diameter measurement taken from an ultrasound during assessment, and the three-dimensional area involved in the catheter to vessel ratio. Graphical representations of calculations will be shown to portray the historical change catheter to vessel ratio has undergone from the “rule of thumb,” to the 1/3 to 2/3, and moving to the present 45% rule.

Results: Through calculations based on the area of the 33% and 45% rule, a simple tool will be presented to help guide the bedside clinician to make informed decisions when placing peripherally-based vascular devices.

Implications: Increasing the understanding and utilization of catheter to vessel ratio will lead to a safer, more consistent, approach to device placement. The future of evidence-based data relies on the clinician to capture accurate vessel measurements and device-related outcomes, based around catheter to vessel ratios. This will lead to a more dependable data pool, propelling the field of vascular access forward, improving patient outcomes.
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