# Liver Doppler Ultrasound: A Practical Guide

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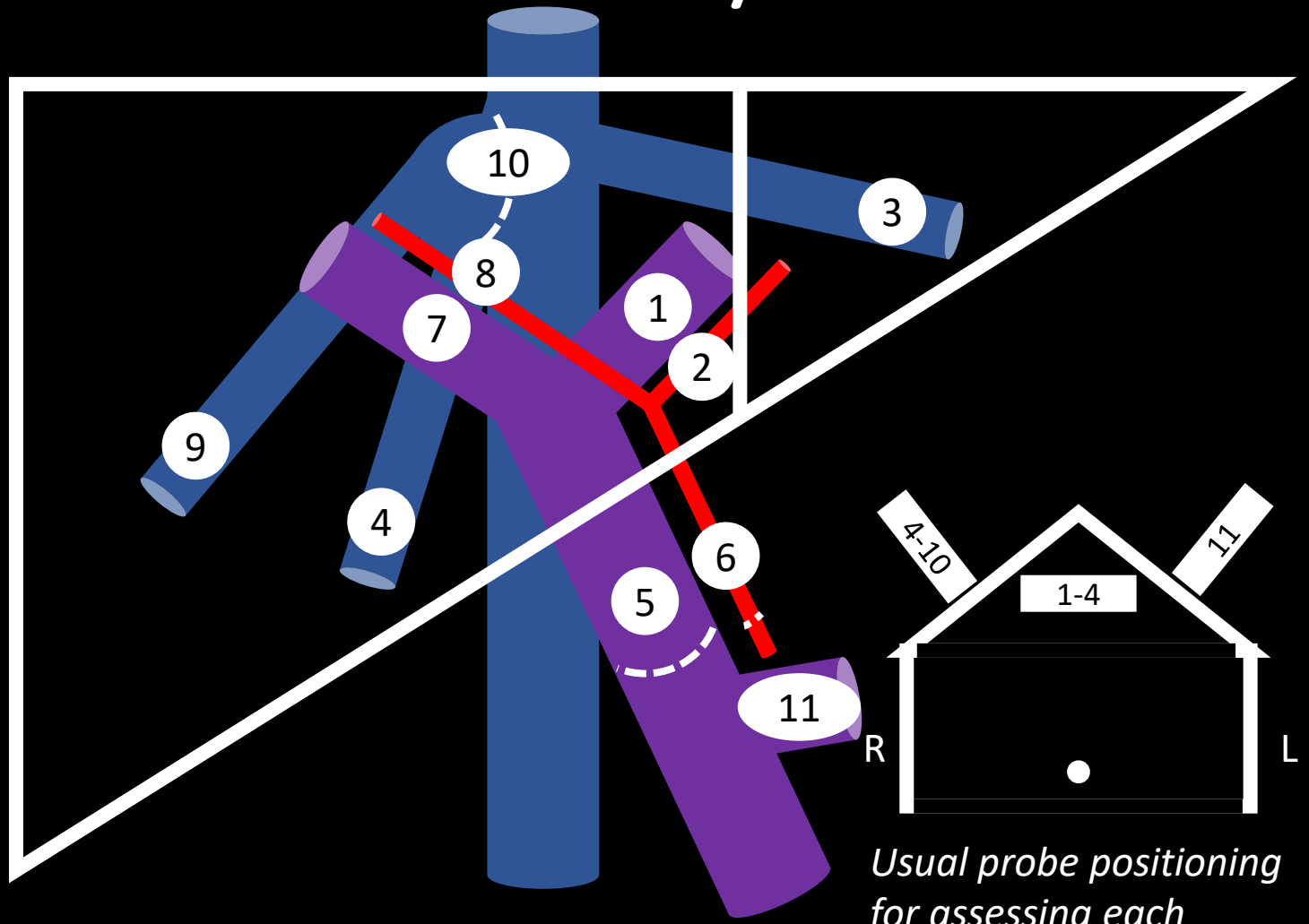
## Learning objectives

To understand techniques for obtaining colour Doppler and pulse wave Doppler images of the liver vasculature:

1. Understand the vessels that should be assessed
2. Be able to use colour and pulse wave Doppler optimisation techniques
3. Be familiar with the appearance of normal and abnormal colour / pulse wave Doppler
4. Be aware of pitfalls during liver Doppler examination and how to avoid them

Hepatic arteries
Portal vein
Hepatic veins

# Vascular anatomy




*Anastomoses in liver transplants*



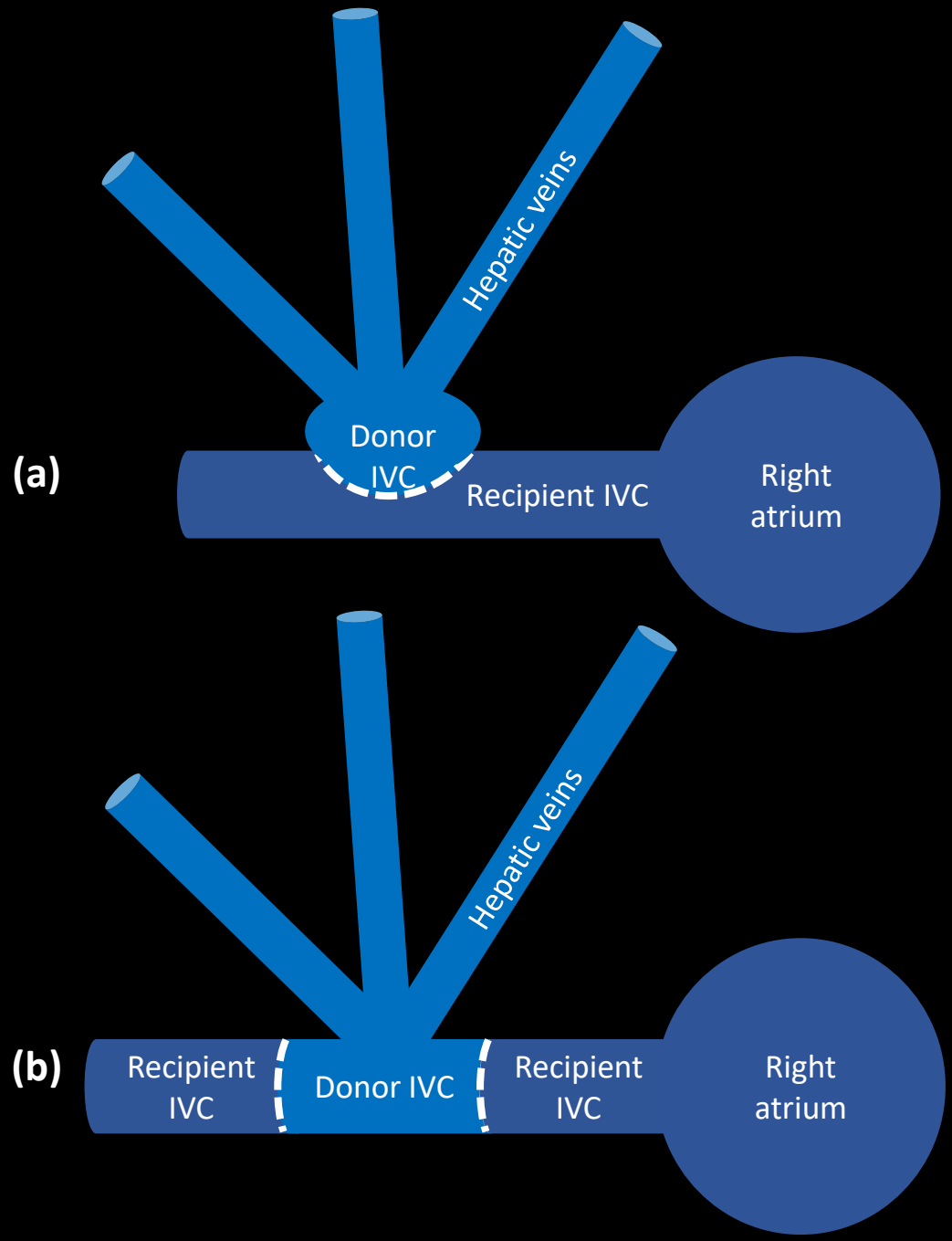

*Usual probe positioning for assessing each vessel*

1. Left portal vein branch
2. Left hepatic artery
3. Left hepatic vein
4. Middle hepatic vein
5. Portal vein
6. Hepatic artery proper
7. Right portal vein branch
8. Right hepatic artery
9. Right hepatic vein
10. IVC
11. Splenic vein

*The vessels can be assessed in any order, but this order is often most efficient*

# Transplant anastomoses

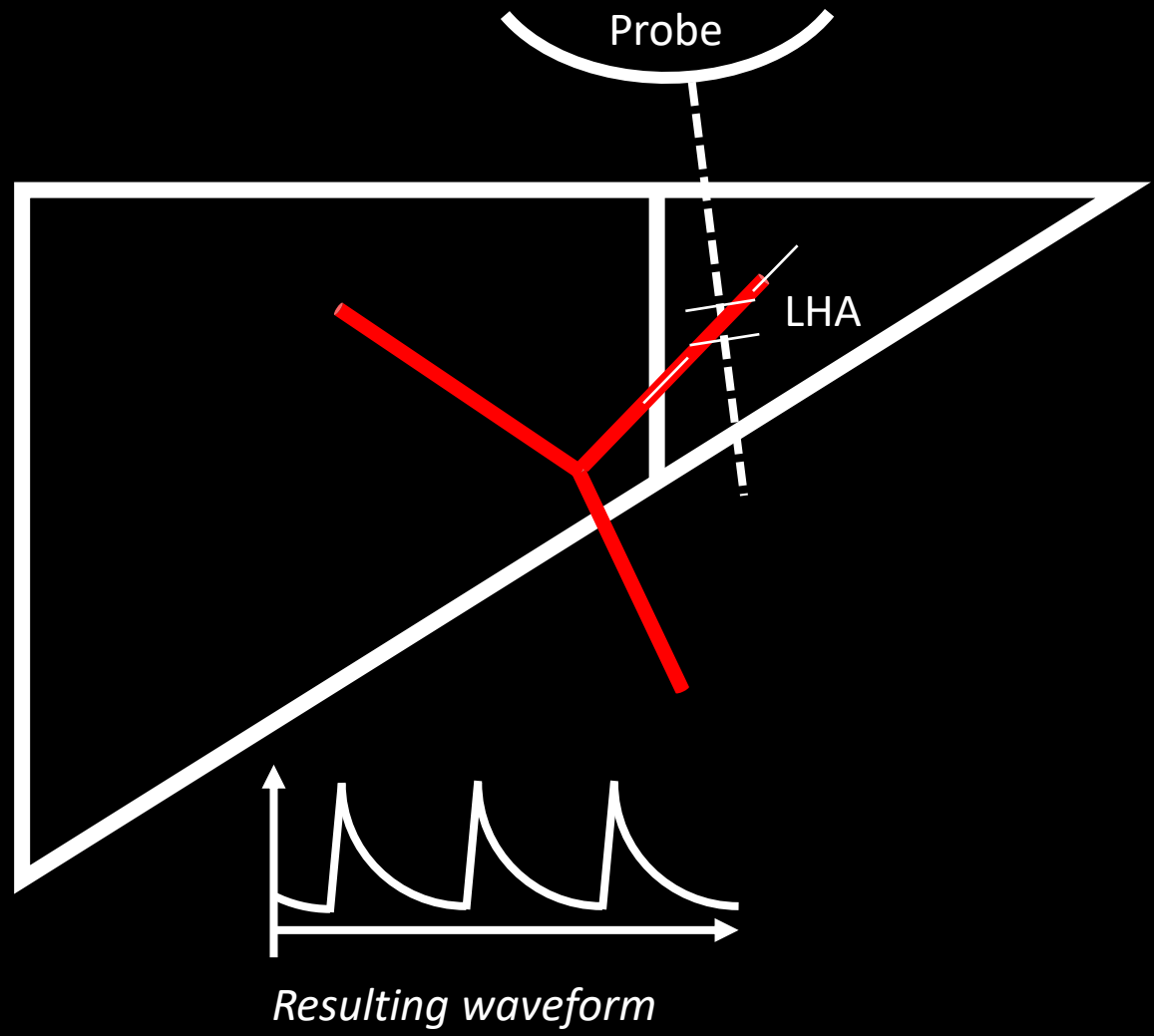
- Common IVC techniques are (a) piggy back and (b) end-to-end anastomoses
- Portal vein anastomosis is almost always end-to-end
- Hepatic artery usually implanted on to recipient hepatic artery (less commonly an aortic conduit - either infrarenal or supracoeliac)
- Bile duct anastomosis also end-to-end (except in PSC, or for second and subsequent transplants where a Roux loop is used)



# Principles of pulse wave Doppler

*Pulse wave gate*

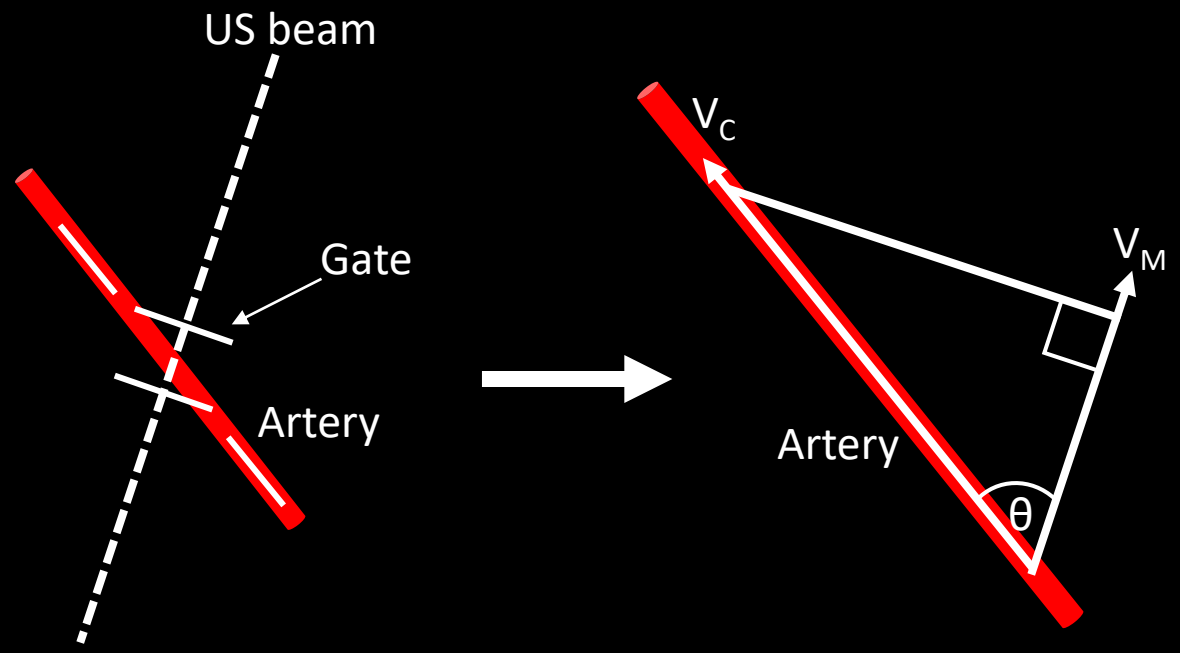
- The pulse wave gate is the area which is sampled and converted into a waveform of velocity vs time
- The size of the gate dictates the sampled length
  - Small gates minimise non-target sampling and background noise
  - Large gates are useful for vessels in an oblique plane which swing with respiration
- Angle correction is essential for accurate velocity measurement (next slide)



# Principles of pulse wave Doppler

## *Angle correction*

- The angle of the vessel from the beam is measured by the user
- The pulse wave velocity scale is multiplied by 1/cos θ
- Where θ > 60˚, cos θ approaches 0
- Therefore **angle correction 60-90˚ is unreliable** as the calculated velocity is affected greatly by small changes in θ
  - In practice this means that vessels that are horizontal on screen are not useful for Doppler assessment



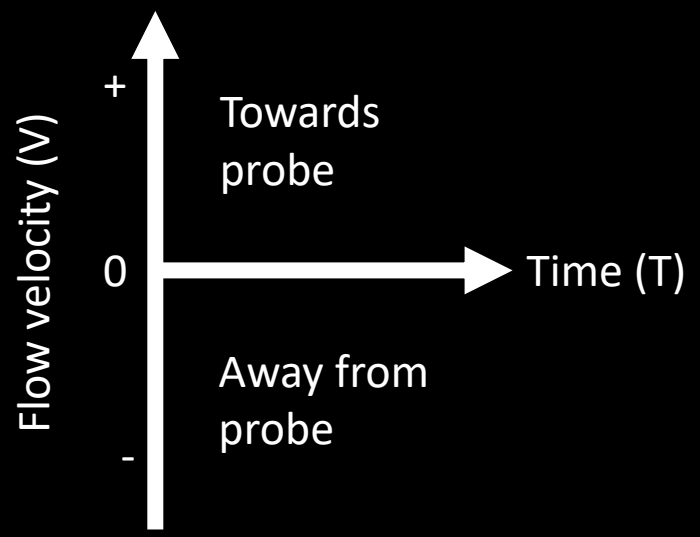

θ = angle for correction, $V_M$ = measured velocity, $V_C$ = corrected velocity

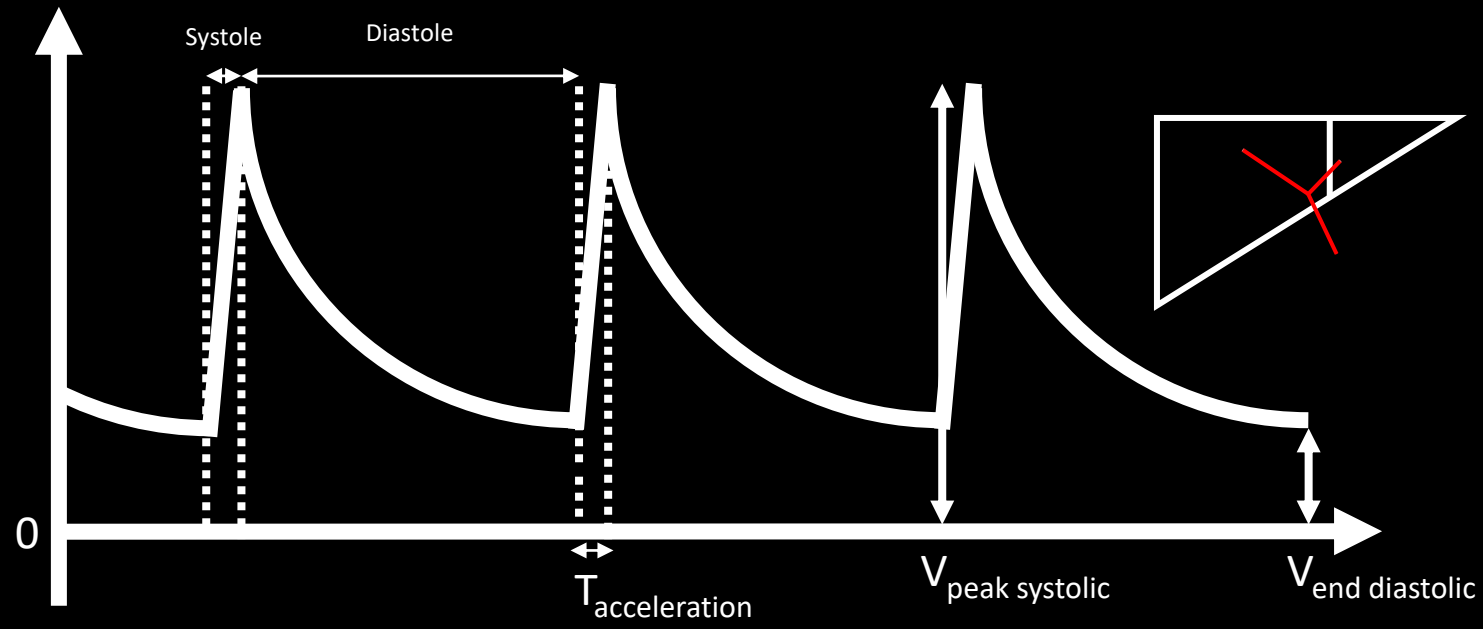
**$V_C = V_M / \cos \theta$**

*$V_c$ is fully described as $V_c=(\Delta F)(C) / 2(F_t)(\cos\Theta)$, where C = the speed of sound in tissue (1540 m/sec), F = Doppler frequency shift, and $F_t$ = transducer frequency (McNaughton, D.A. and Abu-Yousef, M.M. (2011). Doppler US of the Liver Made Simple. RadioGraphics, 31(1), pp.161–188.)*

# Principles of pulse wave Doppler

## *Arterial waveforms*




*A normal low resistance (visceral) arterial waveform*

A normal hepatic arterial pulse wave has a rapid upstroke in systole and preserved end diastolic velocity (approximately 20-40% of peak systolic velocity).

Although resistive index can be measured and quoted, it is not essential. A full discussion is beyond the scope of this article!

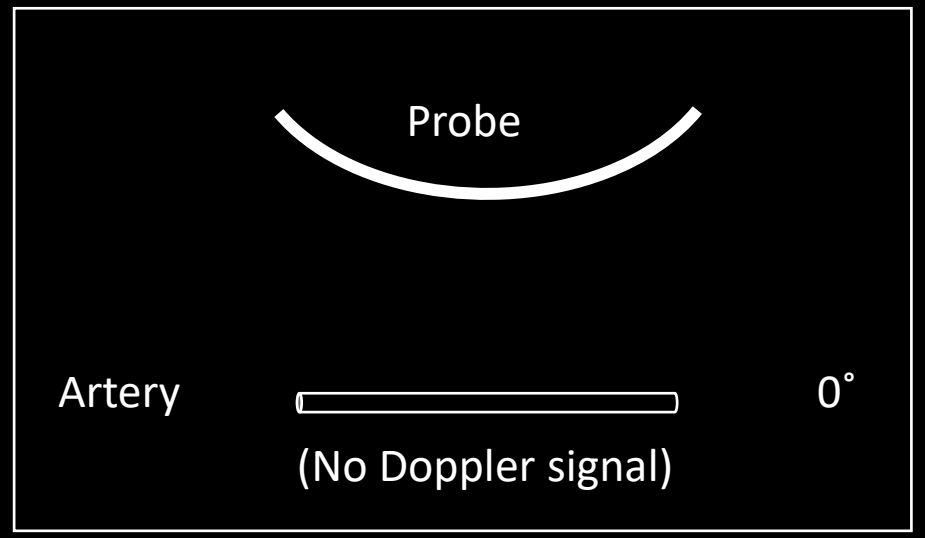
# Pitfalls and troubleshooting

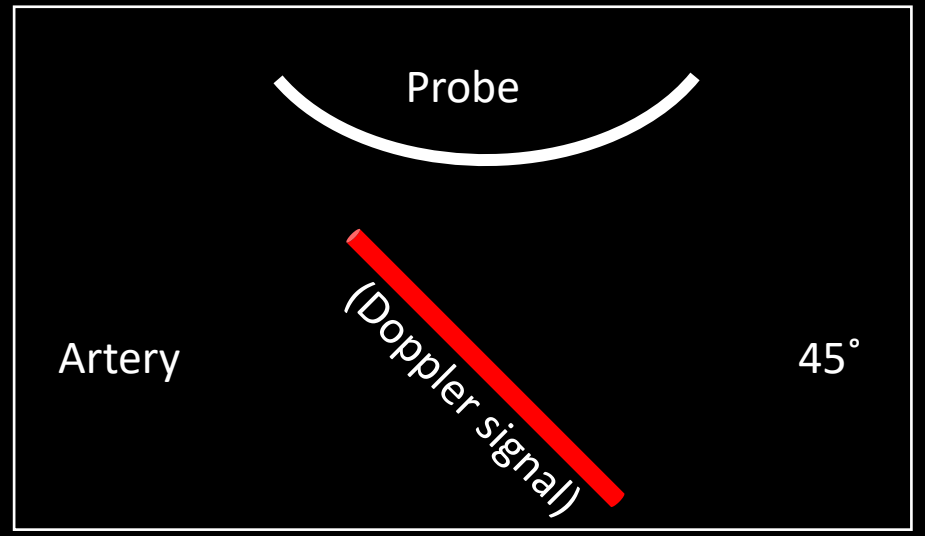
Pitfall:

- Flow will appear absent in a vessel parallel to the probe
- This may mimic thrombosis

Troubleshooting:

- Adjust the probe position to assess the vessel from another angle
- Increasing the Doppler colour gain may elicit flow if unable to alter angle, as can using power Doppler



# Pitfalls and troubleshooting

Pitfall:

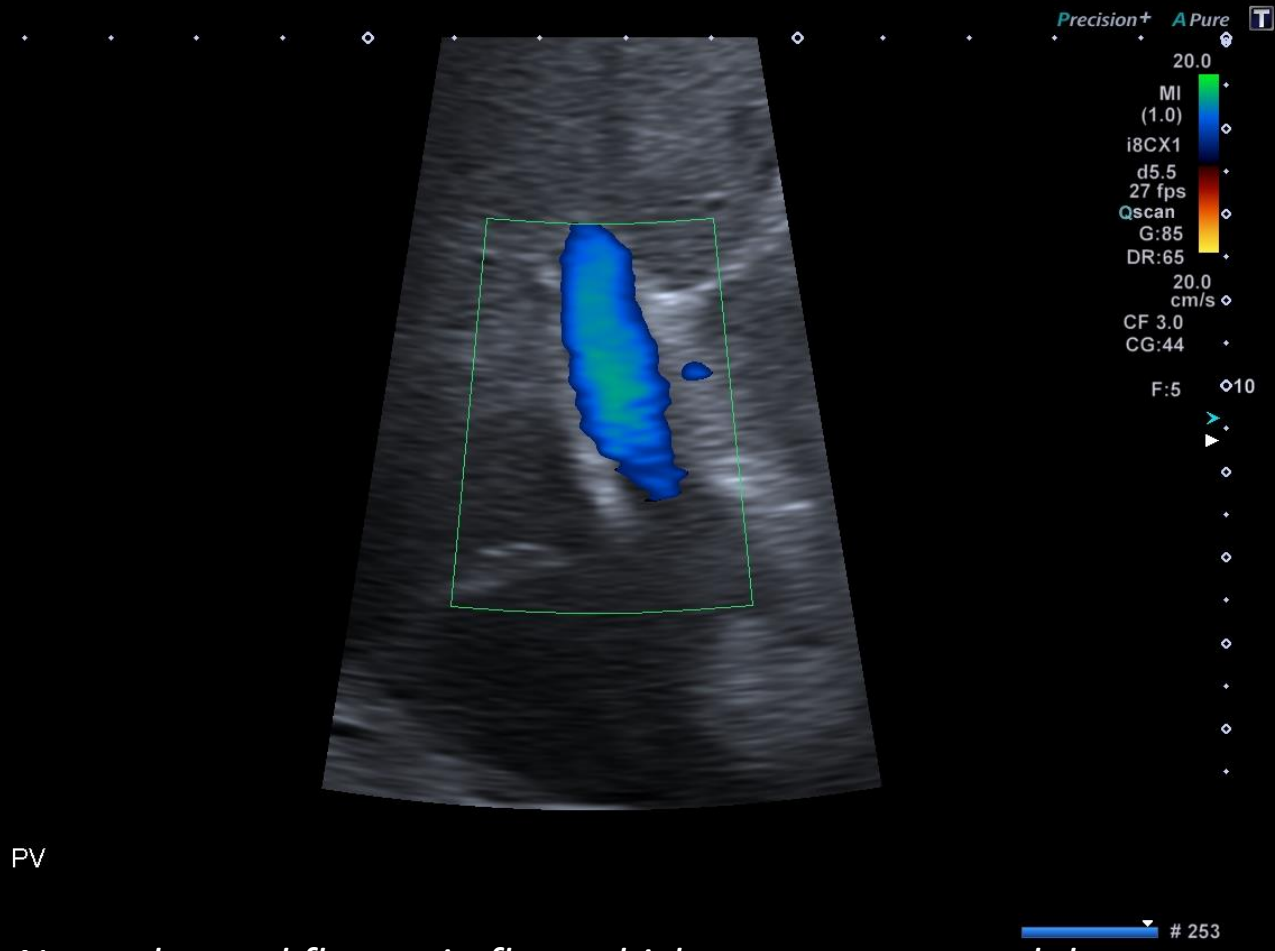
- Accidental inversion of the Doppler scale can make normal flow appear reversed

Troubleshooting:

- Always check the Doppler scale to ensure this is not the case


Conventional


Inverted




*Normal portal flow vein flow which appears reversed due to an inverted Doppler scale*

# Pitfalls and troubleshooting

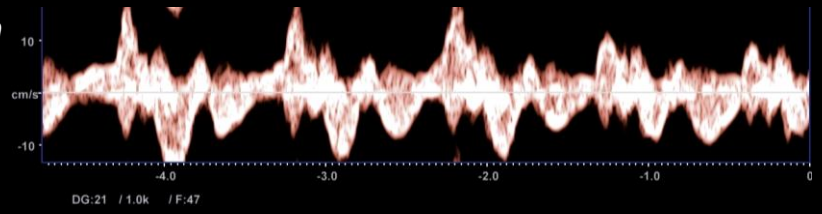
Pitfall:

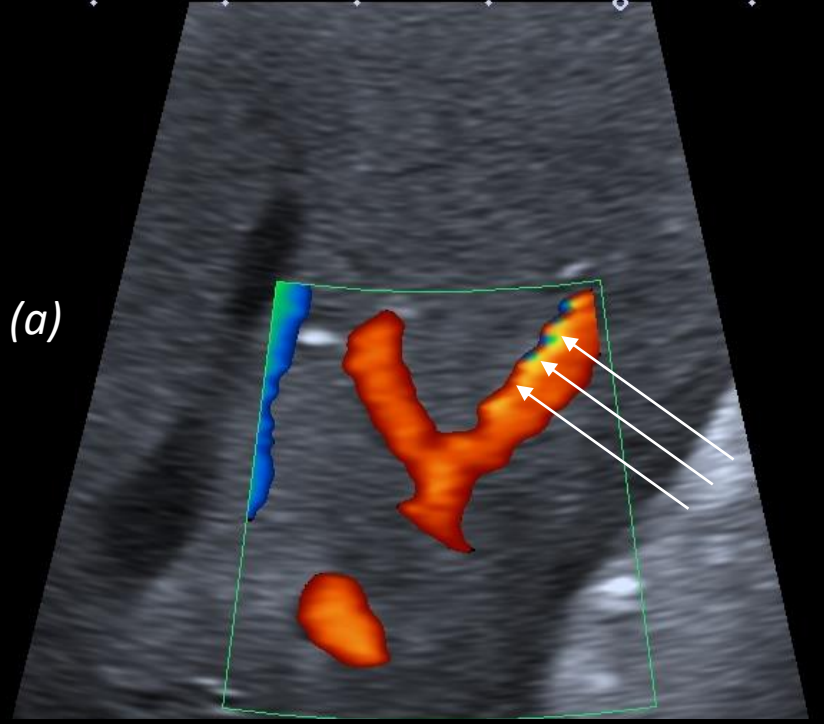
- Unable to find a small calibre hepatic artery
- This may raise undue concern for arterial thrombosis

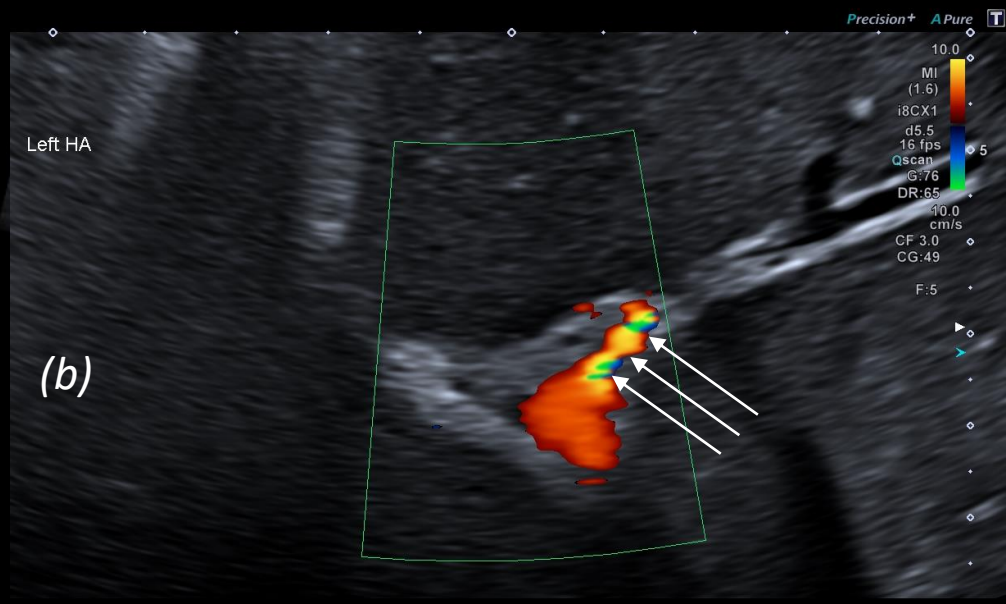
Troubleshooting:

- Decrease the Doppler scale and look for colour aliasing adjacent to a portal vein branch (a & b)
- Increase Doppler colour gain
- Zoom in
- Image in right lobe (left lobe is susceptible to cardiac pulsation artefacts) [1]
- Search along portal vein branches as hepatic arteries always run here

*[1] Chaotic pulse wave signal in the left lobe related to cardiac pulsation*



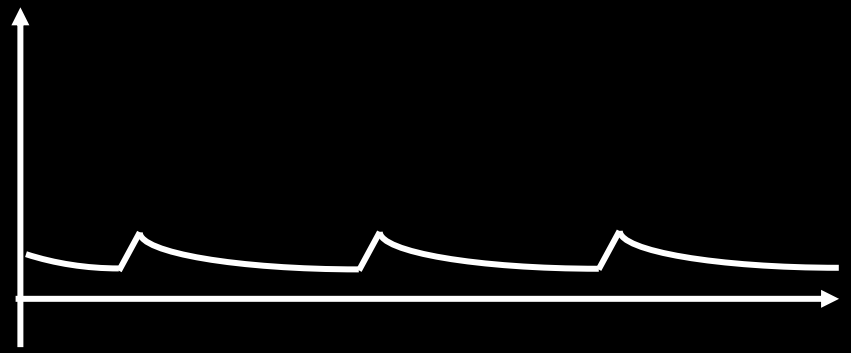
# Pitfalls and troubleshooting

Pitfall:

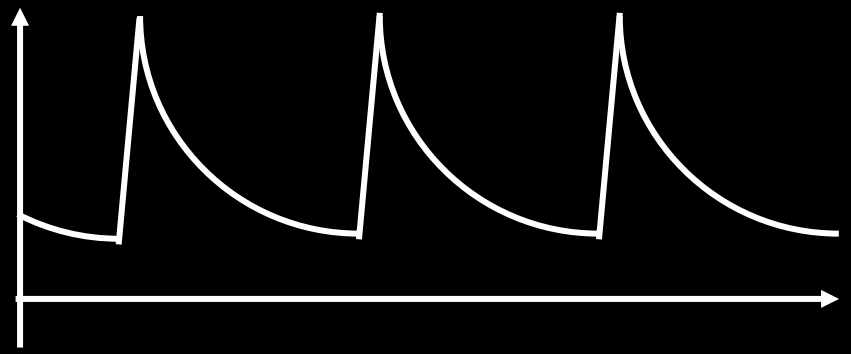
- Setting the pulse wave scale too high will compress the arterial waveforms
- This may appear *tardus et parvus* when the flow is actually normal

Troubleshooting:

- Reduce the scale so the peak velocity is at the top of the y-axis

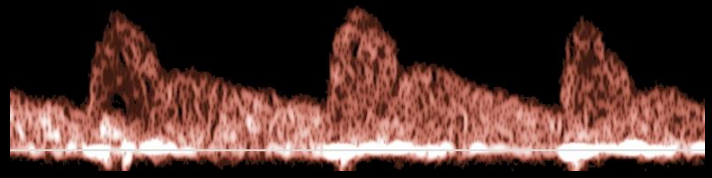
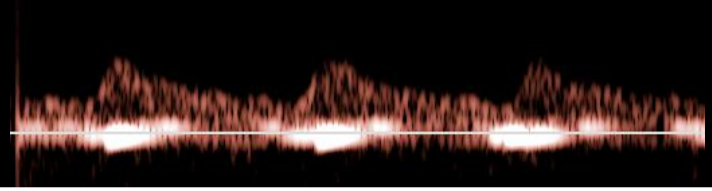
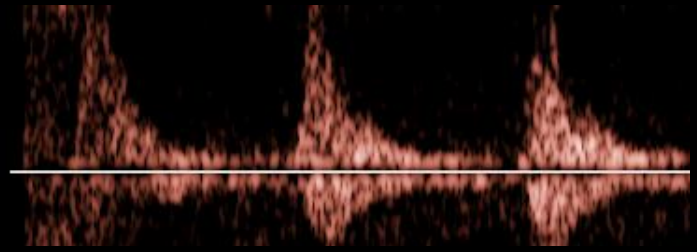


*Normal arterial waveform, with inappropriate axis appearing tardus et parvus*



*Normal arterial waveform*

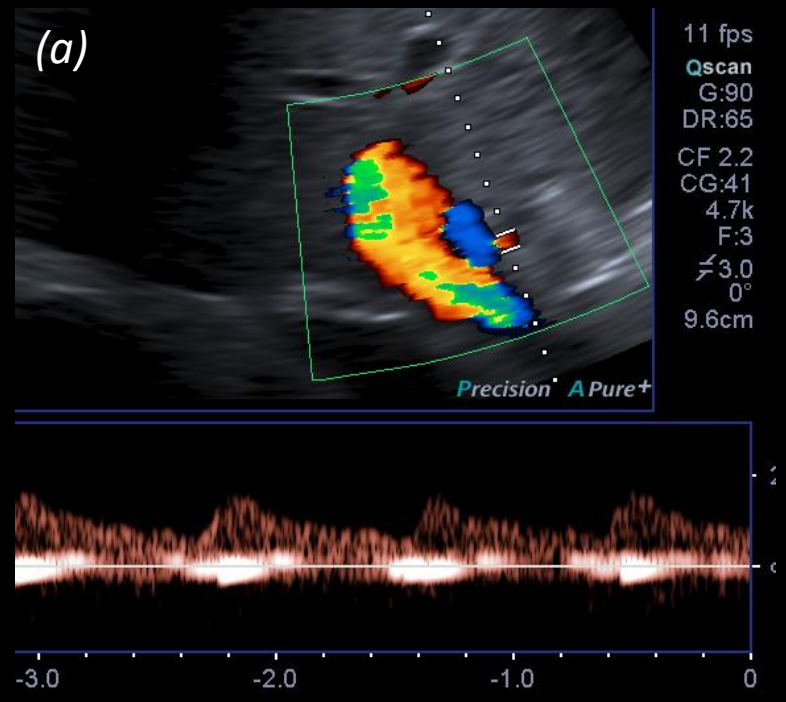
# Abnormal arterial waveforms

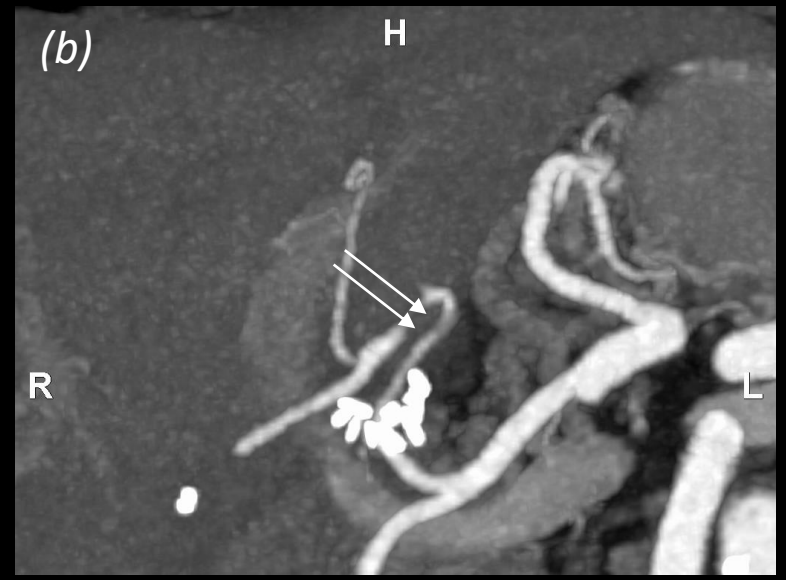
| Waveform | Systolic upstroke | End diastolic flow | Causes | Waveform |
|---|---|---|---|---|
| **Normal** | Fast | Present | |  |
| ***Tardus et parvus*** | Slow | Present | -Kinked artery<br>-Arterial stenosis *(upstream of Doppler gate)* |  |
| **High resistance** | Fast | Minimal/ none/ reversed | -Early post-op<br>-Rejection<br>-Arterial stenosis *(downstream of Doppler gate)* |  |

# *Tardus et parvus* waveform

*Case 1*

- *Tardus et parvus* waveform was identified on US (a)
- Subsequent CT demonstrated a proximal stenosis in the hepatic artery proper (b)
- This stenosis restricted flow in the artery, resulting in slow systolic upstrokes
- Doppler gate was positioned downstream of the stenosis

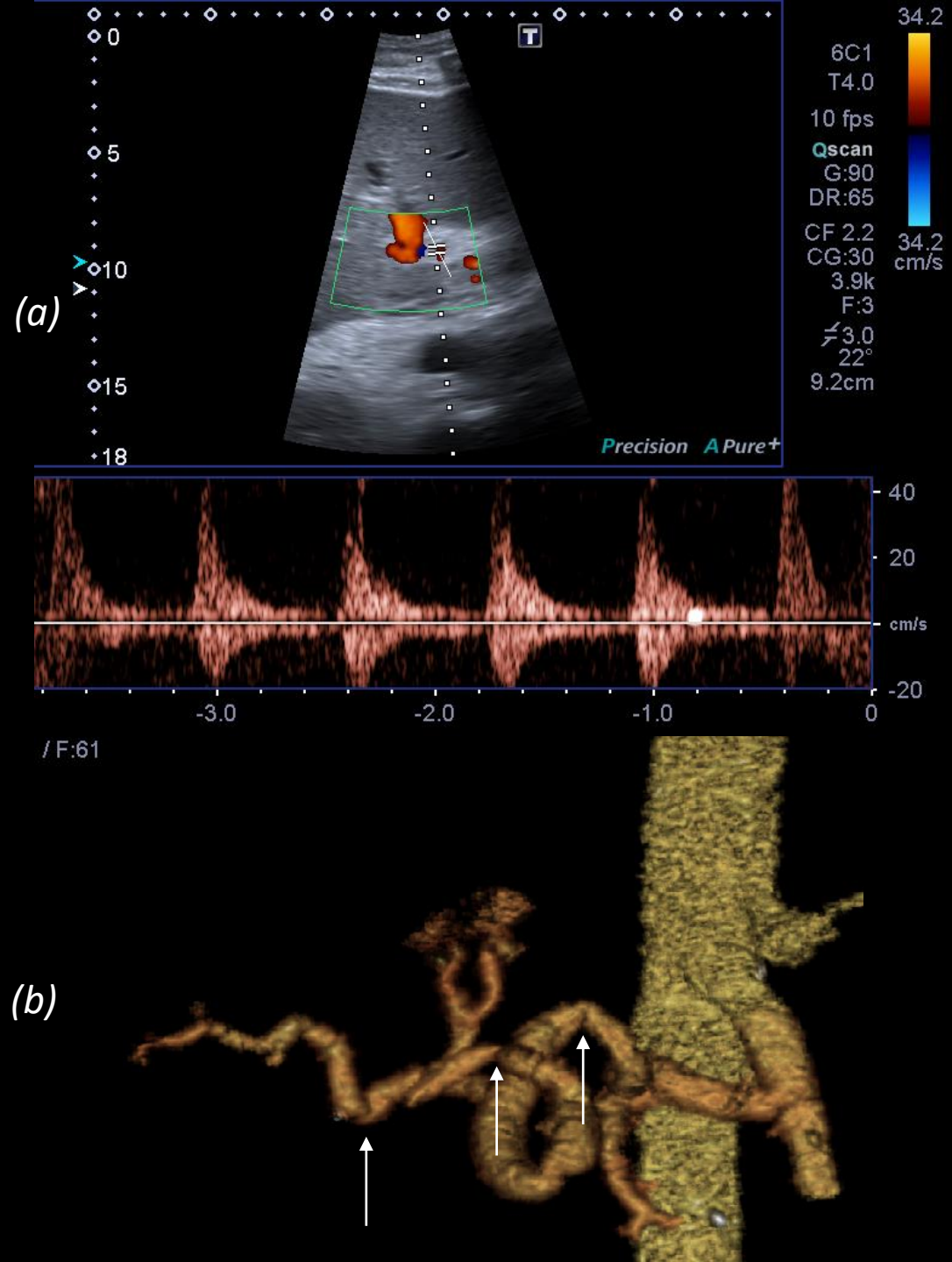


# High resistance waveform

*Case 2*

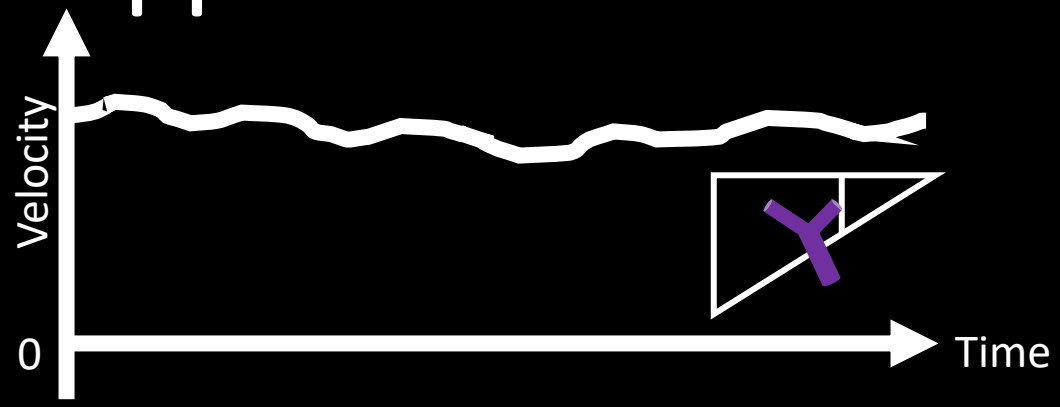
- High resistance waveform was identified on US (a)
- Subsequent CT showed arterial kinking distal to where the Doppler gate was positioned (b)
- These kinked arteries provided areas of resistance to arterial flow
- This limited flow velocity during end diastole when pressure is low



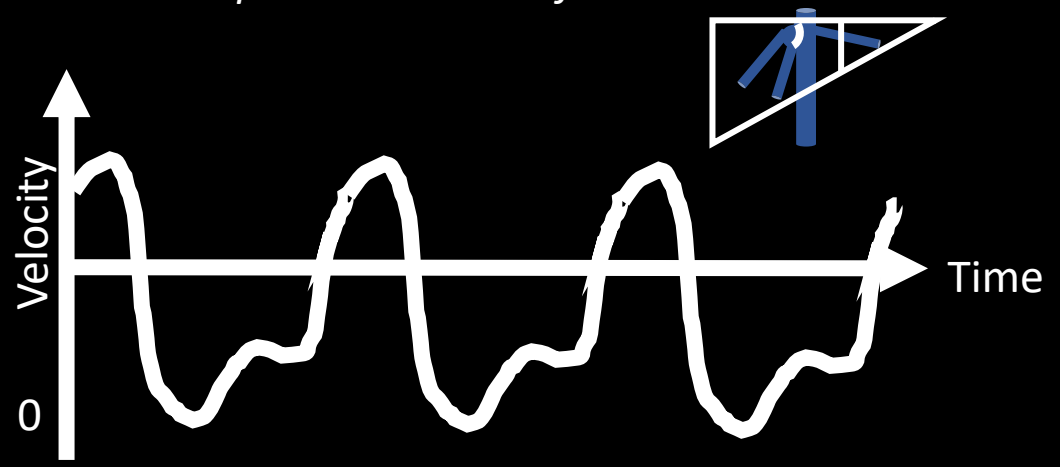
# Principles of pulse wave Doppler

## *Venous waveforms*

- Normal portal vein waves are hepatopetal [1] and phasic [2]
- Normal hepatic vein waves are triphasic and relate to the cycle of the right side of the heart [3]. Abnormal pressure and flow in the right atrium (e.g. AF, tricuspid regurgitation) affects these waveforms.
- Waveforms in the IVC are similar to the hepatic veins
- The splenic vein should be assessed to ensure it is patent




*Normal portal vein waveform*




*Normal hepatic vein waveform*

*[1] Flow from the portal vein to the liver*

*[2] Phasicity arises from both the cardiac cycle and respiratory cycle resulting in superimposed fast and slow cycles in the waveform*

*[3] Scheinfeld, M.H., Bilali, A. and Koenigsberg, M. (2009). Understanding the Spectral Doppler Waveform of the Hepatic Veins in Health and Disease. RadioGraphics, 29(7), pp.2081–2098.*

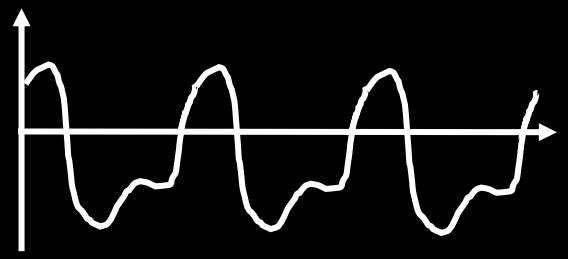
# Abnormal venous waveforms

**Portal vein**

- Absent PV flow suggests thrombosis
  - Always assess on B-mode as well as Doppler to look for echogenic thrombi (may be masked by Doppler overlay)
- Slow PV flow (< ~12cm/s) / reversal suggests portal hypertension

**Hepatic veins**

- Absent/reversed flow suggests HV thrombosis (Budd-Chiari)
- Dampened/non-phasic flow suggests liver parenchymal disease e.g. cirrhosis
- If the hepatic vein pulse wave Doppler measurement is taken centrally within the liver, rather than close to the IVC, it can appear artefactually damped



*Normal HV waveform*

*Dampened HV waveform*

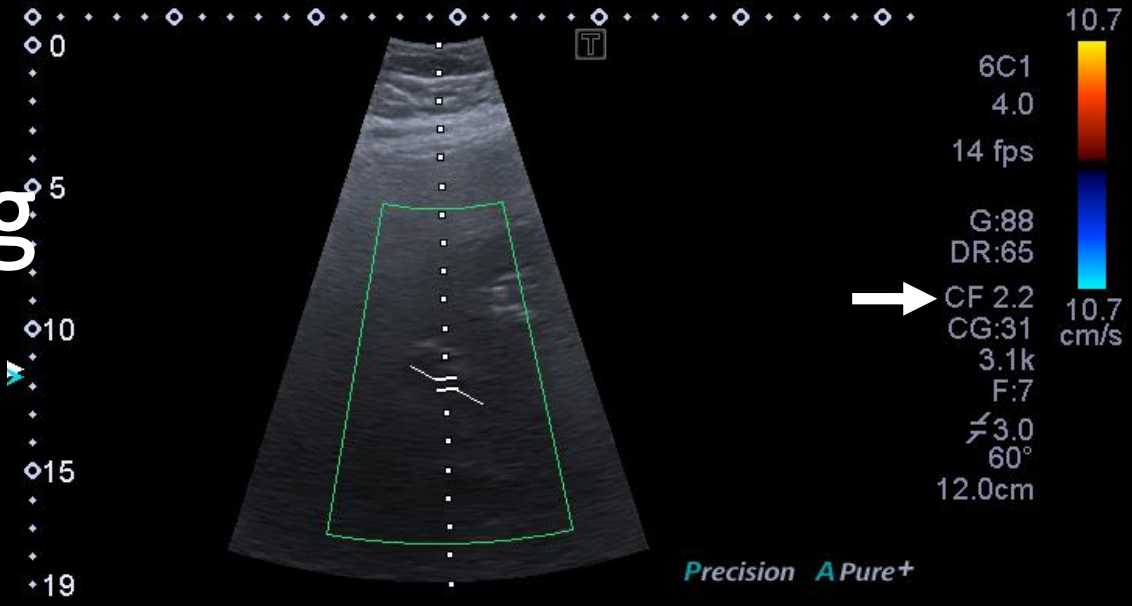
# Pitfalls and troubleshooting

Pitfall:

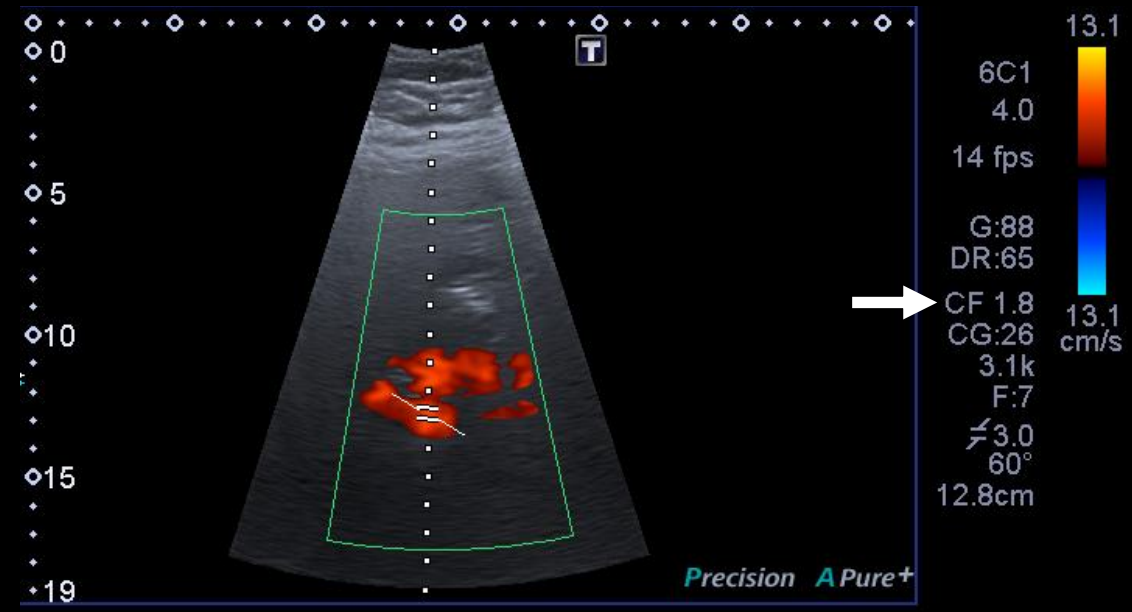
- If there is high attenuation of the ultrasound beam (e.g. hepatic steatosis) Doppler flow may appear absent
- This mimics thrombosis

Troubleshooting:

- Reduce Doppler frequency
- Change probe position to minimise distance from probe to vein
- Use power Doppler




*Default colour Doppler frequency*

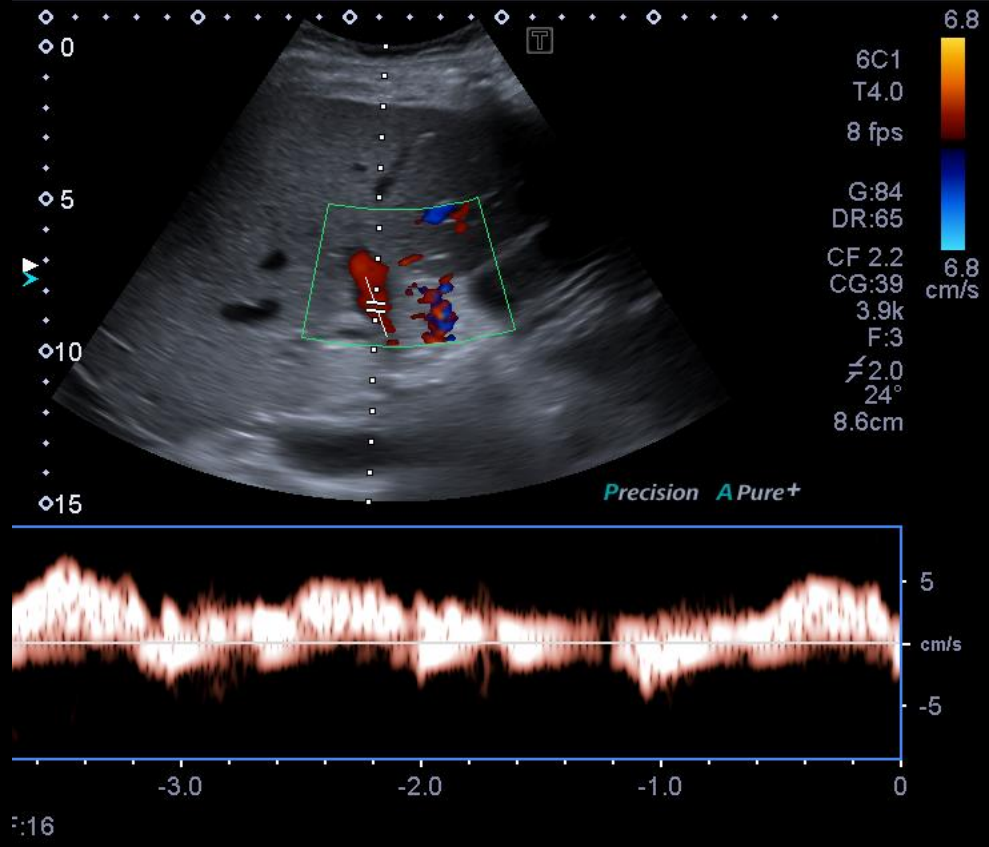



*Reduced colour Doppler frequency*

# Portal vein thrombosis

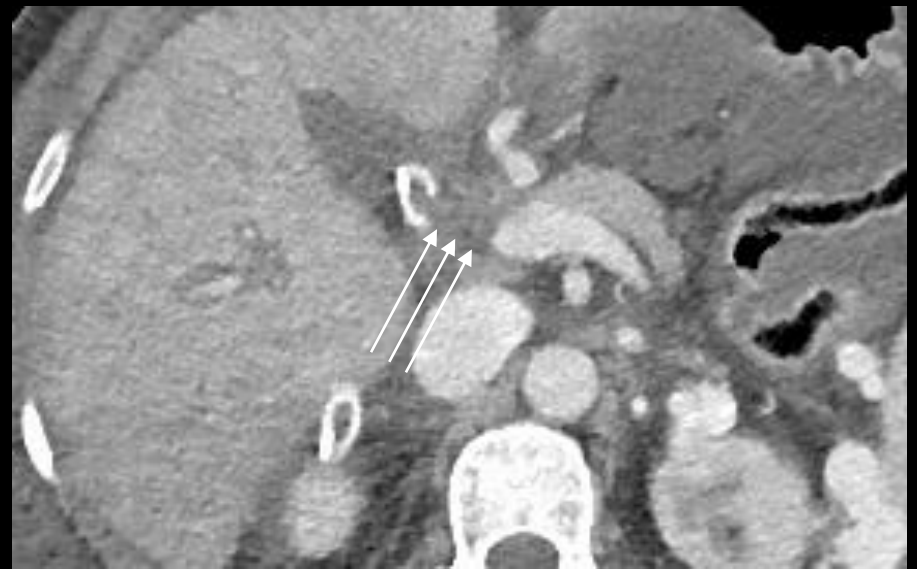
*Case 3*

*(a)*




- US identified minimal portal flow at the hilum (a): flow is sluggish (2-5 cm/sec)and unconvincing
- Despite attempts to optimise colour Doppler by reducing the scale, convincing flow could not be demonstrated
- CT identified acute portal vein thrombosis (b) in this recent liver transplant

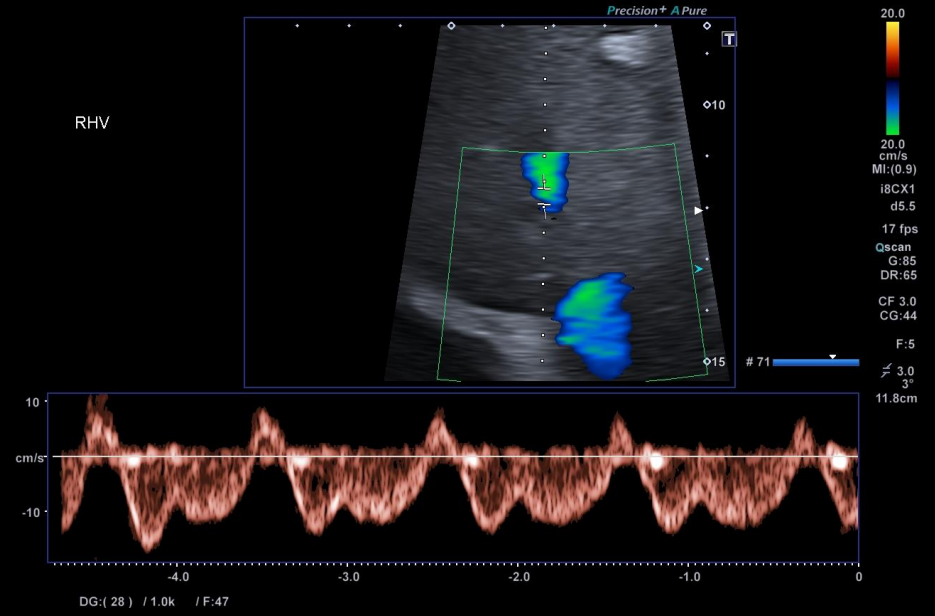
*(b)*



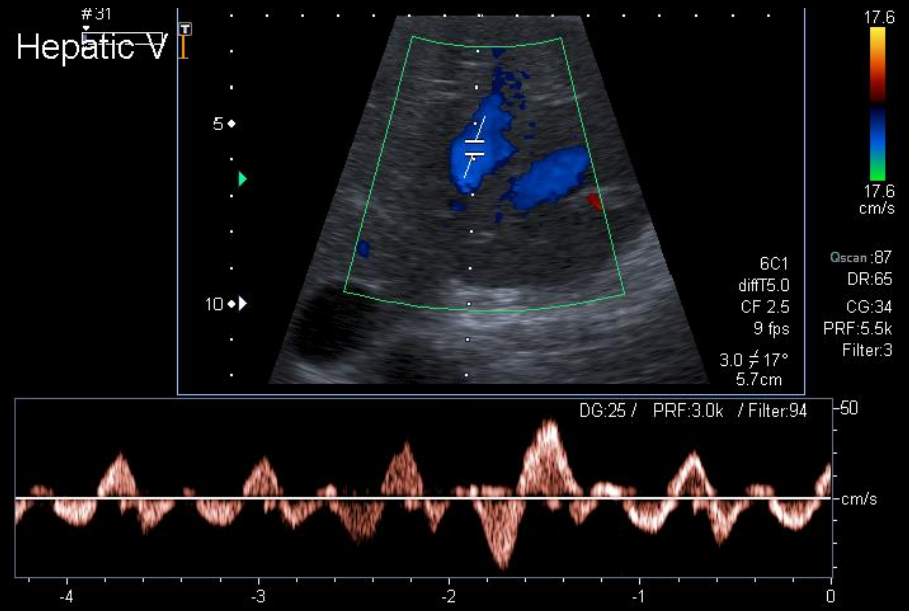
# Tricuspid regurgitation

*Case 4*

- In tricuspid regurgitation, right atrial pressures are high during ventricular systole
- This results in abnormally fast flow towards the probe (above the baseline) during systole
- This may be an incidental finding and echocardiography can be suggested




*Normal hepatic vein waveform*



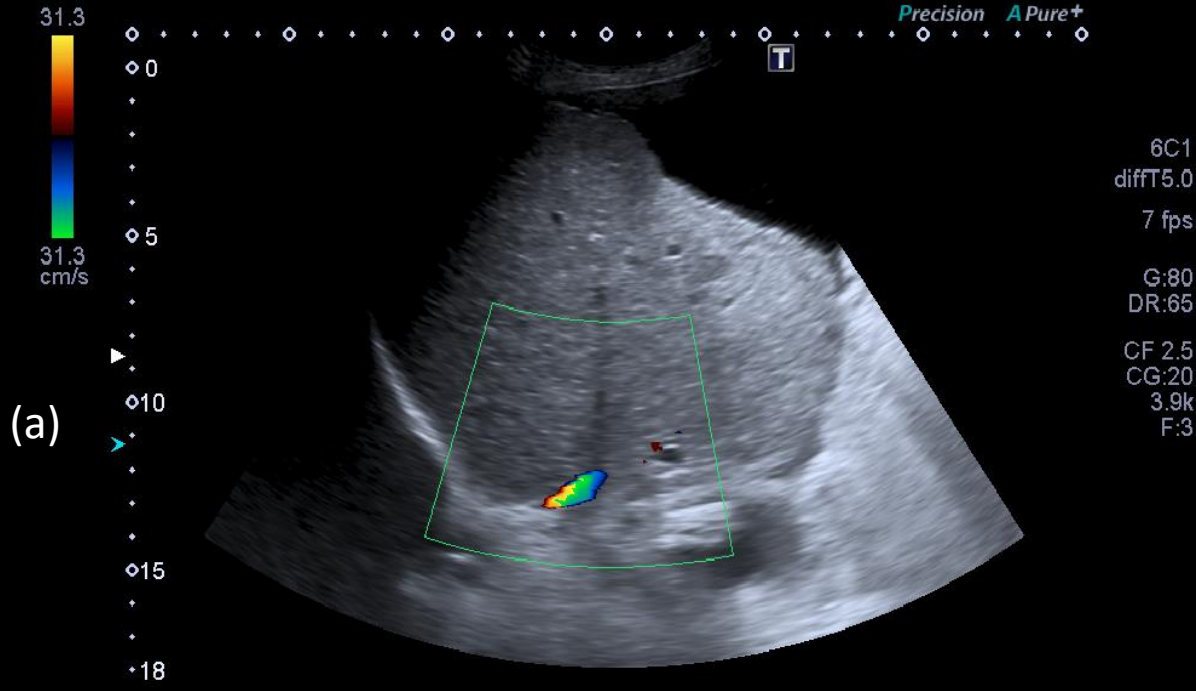

*Tricuspid regurgitation*

# IVC stenosis

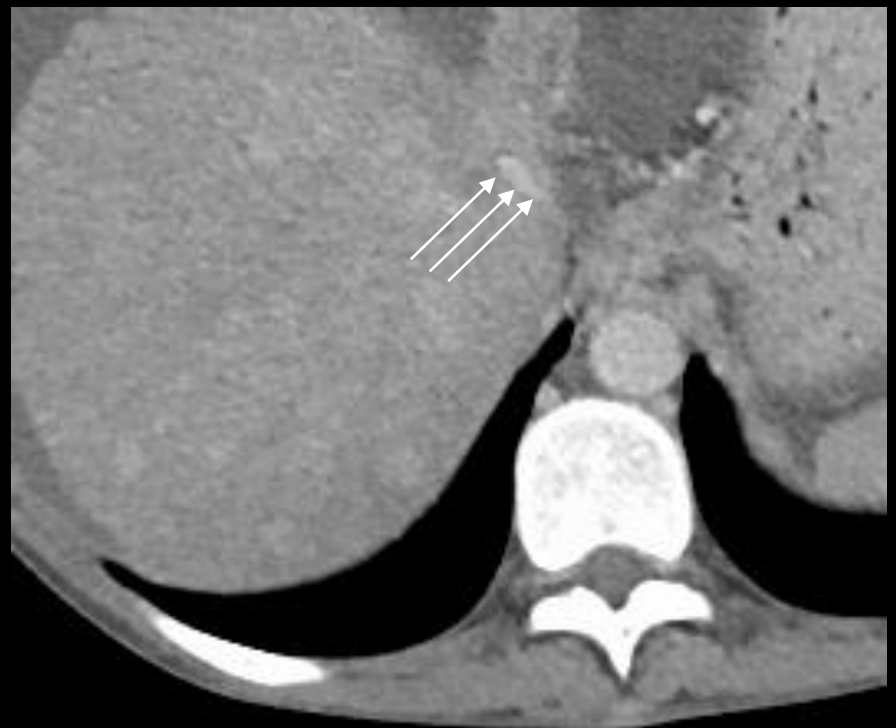
*Case 5*

- US demonstrated a small calibre inferior vena cava (a)
- This was subsequently confirmed on CT a stenosis within the native IVC (b)
- This was part of a work-up for liver transplant and is a key finding to communicate with the transplant surgeons

(a)




(b)



# Summary

- Angle correction is essential for accurate measurement of flow velocity
- Angles >60˚ give unreliable calculated flow velocities
- Small calibre hepatic arteries can be unmasked by reducing the colour Doppler scale and looking for aliasing
- A pulse wave scale set too high may make a normal waveform appear *tardus et parvus*
- Reducing the colour Doppler frequency may unmask flow in the portal vein
- The splenic vein should be assessed in patients after liver transplant
- Abnormal flow in the right atrium (e.g. AF, tricuspid regurgitation) may be identified using pulse wave Doppler
- Hepatic vein pulse wave Doppler should be assessed as close to the IVC as possible