Blunt cerebrovascular injuries: anatomic and pathologic heterogeneity produce management uncertainties.

**Blunt cerebrovascular injury (BCVI)**

**What is known**
1. Rare
2. Can involve the carotid and/or vertebral arteries
3. Most are asymptomatic until cerebral stroke occurs
4. Lesions visualized with special vascular imaging

0.5% of blunt trauma admissions have a BCVI (~3% in patients with ISS > 15)

Two common mechanisms of injury
1. Hyper-extension of head stretches carotid artery and disrupts intima.
2. Fractured bone (cervical spine or skull base) punctures vessel.

**Question #1:** Who should have a screening vascular exam?

High risk injury patterns associated with BCVI that justify screening

- Cervical spine fracture
- Basilar cranial fracture into carotid canal of petrous bone
- Unexplained neurological deficit & ischemic stroke
- Le Fort II or III facial fracture (mandible or maxilla)
- Traumatic brain injury with admission GCS < 6
- Cervical hematoma/cervical bruit
- Woman are higher risk than men (BCVI in 18% screened women and 11% of screened men)

Over 12 months

594 patient met screening criteria

128 patients (22%) had 163 injured vessels
- 99 carotid
- 64 vertebral

Fabian, J Trauma 2014

**CT scan is the preferred screening diagnostic study.**


594 high risk patients were screened with 64-channel CTA and then had Digital Subtraction Angiography.

<table>
<thead>
<tr>
<th>CTA performance</th>
<th>Carotid arteries</th>
<th>Vertebral arteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity (+/with lesion)</td>
<td>72%</td>
<td>77%</td>
</tr>
<tr>
<td>Specificity (-/without lesion)</td>
<td>84%</td>
<td>86%</td>
</tr>
</tbody>
</table>

Dr. Fabian concludes: “Considering complications, cost and resource demand associated with DSA, their studies suggests that 64-channel CTA should be used as primary screening test”
Denver classification of BCVI.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Luminal irregularity</td>
</tr>
<tr>
<td>2</td>
<td>Dissection with intramural hematoma or raised intimal flap</td>
</tr>
<tr>
<td>3</td>
<td>Pseudoaneurysm</td>
</tr>
<tr>
<td>4</td>
<td>Complete arterial occlusion</td>
</tr>
<tr>
<td>5</td>
<td>Transection and/or arteriovenous fistula</td>
</tr>
</tbody>
</table>

Fabian treats with IV Heparin and target PTT 40-50 seconds; however, he reports Aspirin is also effective.

**Hypothesis:**
Circle of Willis' collaterals protect patients with arterial thrombosis. Many BCVI strokes are embolic.

Off the street stroke

<table>
<thead>
<tr>
<th>Vertebral number</th>
<th>% healed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I</td>
<td>132</td>
</tr>
<tr>
<td>Grade II</td>
<td>48</td>
</tr>
<tr>
<td>Grade III</td>
<td>35</td>
</tr>
<tr>
<td>Grade IV</td>
<td>39</td>
</tr>
</tbody>
</table>

Recent case: "Occlusion of left vertebral artery in a patient without a cervical spine fracture, involved in high speed head-on crash. No neurologic deficits. Treated with aspirin, then 2nd post-injury day, enoxaparin added.

**Three recommendations**

1. Screen "high risk" patients for BCVI using CT angiogram (64-channel).
2. If positive CT angiogram, anti-coagulate!
   - Bleeding risk? => Aspirin 300 mg
   - Minimal bleeding risk? => Heparin
   - A pseudoaneurysm requires long term follow-up
3. Remain vigilant for delayed stroke in first week in patients who screen negative.

**Open Questions regarding BCVI**

1. How long should BCVI be treated?
2. What is optimal anticoagulation therapy?
3. When are endovascular stents indicated?
A 36 year old man is in a high speed head-on collision with a dump-truck. When EMTs arrived he was complaining of shortness of breath and they felt a radial pulse. As he was loaded into the ambulance, he had a PEA arrest and died.

Incised back wall of the aorta opens the vessel distal to left subclavian
There is a complete circumferential tear of the aorta.

Autopsy reveals transection of the aorta and 2.5 liters of blood in left chest.

Blunt thoracic aorta injury
Change in practice over one decade

1997
“Prospective study of blunt aortic injury……”
Fabian et al. J Trauma
207 patients
• all had open repair:
  – Mortality 14%
  – Paraplegia 9%

2008
“Operative repair or endovascular stent graft…”
Demetriades et al. J Trauma
193 patients
• 69 had TEVAR:
  – Mortality 4%
  – Paraplegia 1%
• 46 had open repair:
  – Mortality 24%
  – Paraplegia 2%

Management options to treat the blunt thoracic aorta injury.
“Old”: open repair through a left thoracotomy +/- cardio-aortic shunt
“New”: TEVAR = Thoracic endovascular aortic repair

Prospective study of blunt aortic injury (BAI): helical CT is diagnostic and antihypertensive therapy reduces risk of rupture.
• 58 of 71 patients with BAI were treated with antihypertensive medications to “decrease aortic wall shear force”
  – 36 Rx with [beta]-blocker
  – 21 Rx with [beta]-blocker and nitroprusside
  – 1 Rx with nitroprusside
• 15 patients were treated for days with antihypertensive medication; none ruptured.
  – 6 patients had delayed repair and survived.
  – 9 were managed until death from associated injuries.

Grading of blunt aortic injury

Grade I: small intimal tear
Grade II: small pseudoaneurysm
Grade III: Large pseudoaneurysm
Grade IV: rupture/transection

Paper # 8
Parameters for successful nonoperative management of traumatic aortic injury.

The management of patients with blunt aortic injury is changing!
The added treatment of non-operative management of small lesions
2014; 147: 143-50.

<table>
<thead>
<tr>
<th>Total</th>
<th>TEVAR  N = 45</th>
<th>Open surgery N = 7</th>
<th>Nonoperative Medical N = 45</th>
<th>Mortality related to aorta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I Intimal flap</td>
<td>31 = 32%</td>
<td>3 None</td>
<td>28 With 24 Survivors</td>
<td>none</td>
</tr>
<tr>
<td>Grade II Small pseudoaneurysm</td>
<td>35 = 36%</td>
<td>22 None</td>
<td>13 With 7 survivors</td>
<td>1</td>
</tr>
</tbody>
</table>

58 year old in high speed MVC.  
Assessment: Grade I lesion with a > 95% probability the lesion will be stable or resolve. 
Plan: keep Systolic BP below 120 mm Hg, and repeat CT scan in 1 week.

Lessons learned in the past 15 years:
1. Early rupture can be prevented with immediate control of SBP.
2. One-third of patients have Grade I lesions and do not need a procedure.
3. TEVAR is the preferred procedure.
4. Open repair can save the life of a Grade IV patient, but few surgeons can claim extensive experience.

Guideline for treatment of patients with a blunt thoracic aortic injury
Blunt aortic injury categorized based on CT image

Clinical Practice Guideline of the Society for Vascular Surgery
"When TEVAR covers the left subclavian artery orifice, selective revascularization indicated."

Best Practices promulgated by ACS
1. Use Glasgow Coma Scale
2. Monitor Intracranial pressure using external ventricular drain
3. Treat aggressively increased ICP.
4. Early Craniotomy for a mass lesion
5. Start enteral nutrition within 48 hours
6. Transfusion trigger: Hgb ≥ 7 g/dL
7. Severe TBI deserves 72 hours of treatment
The TQIP guidelines recommend External Ventricular Drain [EVD] is preferable to a subarachnoid bolt. “EVDs combine the capacity to make the diagnosis and treat.”

Increasing intracranial pressure indicates a mass lesion is increasing; the treatment is evacuation of the mass.

The search for effective treatment of Traumatic Brain Injury
“In the US, annual rate of TBI is 1.7 million” US cost annually of TBI = $76 billion

Are there new treatments that improve survival and quality of recovery from TBI?

Glasgow Coma Scale, when summed give the Glasgow Coma Score.

Trauma Quality Improvement Project (TQIP) report is based upon the combined data of over 180,000 patients from 223 trauma centers.

“TQIP reports how an individual trauma center’s performance compares to risk-adjusted benchmarks.”

Papers #7-A and 7-B

Progesterone, “a potent neurosteroid synthetized in the CNS” 180 experimental studies demonstrated progesterone following TBI “reduces cerebral edema, neuronal loss and behavioral deficits and has a neuroprotective effect”

In the United States.

Around the world.


Blunt brain injured patients given either progesterone or placebo.

### In the United States
- **n = 1140**
- Age (median) 35
- Male 73%
- Admission GCS
  - 3: 78%
  - 4-6: 28%
  - 7-8: 53%
  - 9-12: 17%
- Time to 1st dose 3.6 hours

### Around the world
- **n = 1195**
- Age (median) 35
- Male 78%
- Admission GCS
  - 3: 10%
  - 4-6: 45%
  - 7-8: 45%
  - 9-12: none
- Time to 1st dose 7 hours

**Series 1:**
- Around the World at six months follow up
  - The Glasgow Outcome Scale was used to dichotomize each patient.
  - They were categorized as having a favorable or unfavorable outcome.

**Series 2:**
- In the United States; at six months follow up
  - Extended Glasgow Outcome Scale at six months showed no difference between progesterone vs placebo. Stratified by severity of injury on hospital presentation.

**Series 3:**
- “No benefit” to patients with severe TBI from administration of progesterone. *Why did the preliminary studies suggested benefit?*
  - Is there widespread bias in preliminary studies when “there is substantial professional or financial investment in a specific outcome”?
  - There is a need for a “comprehensive review of the TBI translational research strategy.”

### What can we do for TBI patients that helps?

- Avoid hypoxia
- Avoid hypotension
- Operate early to evacuate mass lesions that increase ICP.
**TQIP proclaimed goals of treatment in the ICU of patients with a severe TBI**

If ICP > 20, reduce with three tiered approach

**Tier 1**
- HOB elevated 30 degrees
- PaCO2 30 – 35 mm Hg
- Sedation

**Tier 2**
- If ICP > 25 mm Hg:
  - Hyperosmolar Rx
  - EVD (ventriculostomy)
  - Test for loss of autoregulation (ICP increases as MAP increases).

**Tier 3**
- Neuromuscular paralysis
- 2 twitches on nerve stim
- Propofol coma trial

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**Intracranial pressure monitoring in severe traumatic brain injury:**
Results from the American College of Surgeons Trauma Quality Improvement Program.

The 155 trauma centers reporting to TQIP 10,628 adult patients with severe TBI. Hospitals divided into four quartiles based on % who had an intracranial pressure monitor.

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**Paper #6**

Relationship of collegiate football experience and concussion with hippocampal volume and cognitive outcomes.


Within a group of collegiate football athletes, there was a “significant inverse relationship between concussion and years of football played with hippocampal volume.”

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**Effect of early vs late tracheostomy placement in survival of patients receiving mechanical ventilation.**

Young D, Harrison DA, Cuthbertson, MD, Rowan K D Phil. *JAMA* 2012; 309: 2121-2129

This randomized control trial conducted in 72 ICUs in England. A “pragmatic” trial, meaning included a wide spectrum of patients.

**Patients who had four days of mechanical ventilation, and whom medical providers “guessed” would likely need 7 more days of mechanical ventilation were randomized.**

**Early n = 451**
- 92% had tracheostomy
- Age 64
- Surgery patients: 20%
- Primary Dx: Respiratory failure 60%

**Late n = 448**
- 46% had tracheostomy
- Age 64
- Surgery patients: 21%
- Primary Dx: Respiratory failure 59%

90% of the tracheostomies were percutaneous and at the bedside.
Outcome: no difference in survival

<table>
<thead>
<tr>
<th>Early Tracheostomy</th>
<th>Late Tracheostomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td></td>
</tr>
<tr>
<td>30 Day</td>
<td>30.8%</td>
</tr>
<tr>
<td>1 year</td>
<td>45.9%</td>
</tr>
<tr>
<td>2 year</td>
<td>51.0%</td>
</tr>
<tr>
<td>Ventilated days</td>
<td>13.6</td>
</tr>
<tr>
<td>30 Day</td>
<td>31.5%</td>
</tr>
<tr>
<td>1 year</td>
<td>49.0%</td>
</tr>
<tr>
<td>2 year</td>
<td>53.7%</td>
</tr>
<tr>
<td>Ventilated days</td>
<td>15.2</td>
</tr>
</tbody>
</table>

The early tracheostomy group needed fewer days of sedation (P < .001.)
The authors comment: “A modest reduction in sedative use was seen in patients randomized to early tracheostomy.”

Kaplan-Meier Survival Curve; P = .45

Effect of early vs late tracheostomy placement in survival of patients receiving mechanical ventilation.
Young D, Harrison DA, Guthbertson, MD, Rowan KD Phil. JAMA 2012; 309: 3121-3129

Conclusions
Early tracheostomy did not provide survival benefit or reduce ICU length of stay.
The medical teams were wrong 50% of they times they predicted “patients will likely need > 7 more days of ventilation”.
Early tracheostomy is not justified.

Studied patients in TQIP data base with TBI and who had a tracheostomy

<table>
<thead>
<tr>
<th>Early tracheostomy</th>
<th>Late tracheostomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trach in &lt; 8 days</td>
<td>n=873</td>
</tr>
<tr>
<td>Age</td>
<td>49</td>
</tr>
<tr>
<td>Admit GCS (median)</td>
<td>4</td>
</tr>
<tr>
<td>Head AIS</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9%</td>
</tr>
<tr>
<td>4</td>
<td>46%</td>
</tr>
<tr>
<td>5</td>
<td>46%</td>
</tr>
<tr>
<td>Trach in &gt; 8 days</td>
<td>n=938</td>
</tr>
<tr>
<td>Age</td>
<td>53</td>
</tr>
<tr>
<td>Admit GCS (median)</td>
<td>7</td>
</tr>
<tr>
<td>Head AIS</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>4</td>
<td>30%</td>
</tr>
<tr>
<td>5</td>
<td>44%</td>
</tr>
</tbody>
</table>

Patients who had early tracheostomy did not have a lower odds of death
ET 8.4% versus LT 6.8%

<table>
<thead>
<tr>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator days, median (IQR)</td>
</tr>
<tr>
<td>ICU days, median (IQR)</td>
</tr>
<tr>
<td>Hospital days, median (IQR)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ET (n = 571)</th>
<th>LT (n = 571)</th>
<th>Rate Ratio (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70 (0.66-0.75)</td>
<td>0.70 (0.66-0.75)</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>0.70 (0.74-0.86)</td>
<td>0.80 (0.74-0.86)</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

Tracheostomy shortened ventilator days and ICU days
To trach or not to trach? 
Two tactics: preemptive trach versus wait and see.

Conclusion
Data supports the “wait and see about 10 days.”

Medicare pays more to hospitals for patients whose DRG indicates the patient had > 96 hours of mechanical ventilation through a tracheostomy.

Safety of bedside percutaneous tracheostomy in the critically ill: evaluation of more than 3,000 procedures

3,162 percutaneous dilational tracheostomies

Complications and deaths
12 immediate complications
- airway loss,
- bleeding,
- tube occlusion
5 cases of tracheal stenosis
2 Deaths
- tube dislodgement

Conclusions:
The percutaneous tracheostomy is safe, even in patients with a BMI > 35
Low complications and very low death rates can be achieved by having the procedure exclusively performed by a team who follow a protocol.

Motorcycle rider collides with a wire, presents with stridor, severe agitation and inability to phonate. Lateral C spine shows suspected larynx injury.

An immediate tracheostomy using local anesthesia was completed within 25 minutes of the patient’s arrival.
What should be done to treat the anemia of ICU patients?

“We trod the hard road of trial and error”.

A landmark study
A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care

Comparison of “liberal” and “restrictive” transfusion practices leads to conclusion:
Fewer transfusions and lower hemoglobin (~ 8 g/dL) provides superior results.

Simplistic concept: “Red blood cells are like box cars, and if you want to deliver more oxygen increase the number of box cars.”

<table>
<thead>
<tr>
<th>Hemoglobin entering study</th>
<th>Restrictive strategy (n=418)</th>
<th>Liberal strategy (n=420)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 7/1 g/dL</td>
<td>6/1 - 1 g/dL</td>
<td>6/1 - 1 g/dL</td>
<td></td>
</tr>
<tr>
<td>&gt; 3 organs failing</td>
<td>74%</td>
<td>77%</td>
<td></td>
</tr>
<tr>
<td>Vasoactive drugs</td>
<td>37%</td>
<td>37%</td>
<td></td>
</tr>
</tbody>
</table>

Two strategies:
Transfuse red cell units to keep hemoglobin between either 7 to 9 g/dL or 10 to 12 g/dL

“Kaplan – Meier survival curves were similar”

“Kaplan – Meier survival curves revealed patients under the age of 55 were more likely to die if transfused to Hgb > 10 g/dL”
Effect of erythropoietin and transfusion threshold on neurological recovery after traumatic brain injury: a randomized clinical trial.


In a 2 X 2 factorial design, 200 patients with TBI (exclude GCS 3, fixed dilated)

<table>
<thead>
<tr>
<th>Average Hemoglobin levels</th>
<th>Day 9</th>
<th>Day 16</th>
<th>GOS at 6 months = moderate to good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythropoietin</td>
<td>10.7</td>
<td>10.8</td>
<td>43%</td>
</tr>
<tr>
<td>Placebo</td>
<td>10.9</td>
<td>10.4</td>
<td>39%</td>
</tr>
<tr>
<td>Transfusion trigger 7 g/dL</td>
<td>9.7</td>
<td>9.6</td>
<td>42%</td>
</tr>
<tr>
<td>Transfusion Trigger 10 g/dL</td>
<td>11.4</td>
<td>11.2</td>
<td>34%</td>
</tr>
</tbody>
</table>

No difference in survival in the two groups. Administration of Epo and transfusion trigger of 10 g/dL did not lead to superior outcome.

Caution: transfusion to a keep Hgb > 10 g/dL increased prevalence of thromboembolic events.

A randomized control trial: neither transfusion to keep Hgb > 10 g/dL nor erythropoietin improved neurological outcome at 6 months.

Iron loading did not push up the erythropoiesis.

In an ICU with a hemoglobin < 12 g/dL, had no measurable benefit from IV infusion of 100 mg of iron sucrose thrice weekly.
What is best treatment for the anemic patients in an ICU?
Transfuse to keep Hgb > 7 g/dL

The most recent evidence refutes earlier reports that erythropoietin can “boost” the hemoglobin of patients and benefit them.

Implied old blood (on the shelf more than 28 days) is bad blood when you are critically ill.

The axioms of damage control resuscitation
On ED arrival identify a patient likely to need a massive transfusion.

Begin resuscitation with intravenous infusion of universal donor red blood cells.

Aim to achieve a SBP of 90 mmHg, and then move promptly to OR/angiography suite and control hemorrhage.

For every unit of RBC give one unit of FFP and one unit of platelets. The 1:1:1 goal!

Surgeons should rely upon damage control methods:
Prompt hemostasis
Abbreviated surgery
Stop the vicious downward cycle of hypothermia, acidemia and coagulopathy

"Damage control resuscitation is required by ~ 10% of Combat Casualties"

Colonel John Holcomb, MC, USA
Surgical Consultant, Iraq.

Notification a seriously injured patient was coming to our FST, the nurse and anesthesia provider set up the Belmont rapid infusion device.

A failed damage control resuscitation:
16 RBC
6 FFP
1(=6U) apheresis platelets

Patients whom the trauma surgeon predicted would “likely need” a massive transfusion were recruited within 60 minutes of ED arrival.

<table>
<thead>
<tr>
<th>1:1: (1 unit RBC) Group (n = 338)</th>
<th>1:1: (2 unit RBC) Group (n = 342)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Age: 34</td>
<td>Median Age: 34</td>
</tr>
<tr>
<td>Male 78%</td>
<td>Male 83%</td>
</tr>
<tr>
<td>Admit SBP &lt; 90 mmHg: 38%</td>
<td>Admit SBP &lt; 90 mmHg: 39%</td>
</tr>
<tr>
<td>Admit Hgb 12 g/dL</td>
<td>Admit Hgb 12 g/dL</td>
</tr>
<tr>
<td>Admit Base Excess -9 mEq/L</td>
<td>Admit Base Excess -9 mEq/L</td>
</tr>
<tr>
<td>Blunt Trauma 55%</td>
<td>Blunt Trauma 55%</td>
</tr>
</tbody>
</table>

Adult injured patients transported to 12 Level I trauma centers

Jungle Operating Room
Howard Baer: 1944

"Damage control resuscitation is required by ~ 10% of Combat Casualties"
**Blood products (median) received during first 24 hours:**

1:1:1 Group → 9 u RBC, 7 u FFP and 12 u Platelets

1:1:2 Group → 9 u RBC, 5 u FFP and 6 u Platelets

**Median FFP/RBC**

1:1:1 Group = 9 u RBC, 7 u FFP and 12 u Platelets

1:1:2 Group = 9 u RBC, 5 u FFP and 6 u Platelets

Blood product units

**Outcome:** no difference in mortality

**24 Hour Mortality**

1:1:1 = 12.7%

1:1:2 = 17.0%  P = .12

**30 day Mortality**

1:1:1 = 22.4%

1:1:2 = 26.1%  P = .26

**Hazard ratio** = 0.83; not significant

**“Fewer patients in the 1:1:1 group experienced death by 24 hours.”**

**First 24 hours**

<table>
<thead>
<tr>
<th>Deaths</th>
<th>First 24 hours</th>
<th>After 30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1:1</td>
<td>43/338</td>
<td>75/338</td>
</tr>
<tr>
<td>1:1:2</td>
<td>58/342</td>
<td>89/342</td>
</tr>
</tbody>
</table>

**Cause of death was Exsanguination:**

1:1:1 31/338 = 9.2%

1:1:2 50/342 = 14.6%

Fewer deaths from exsanguination in 1:1:1.  p = 0.03

**The 1:1:1 tactic is effective and was not associated with increased risk of complications**

Conclusions:

Trauma centers can achieve 1:1:1 transfusion scheme by having pre-thawed plasma.

An injured patient who had bled into shock needs Type O blood transfusion and universal donor FFP (Group A and B).

Early coagulation factor infusion reduced risk of death from exsanguination.

**Summary of Top Ten Trauma papers**

- BCVI is rare, but early diagnosis and anticoagulation reduces risk of stroke
- Blunt Aortic Injuries: most treated with TEVAR or observation combined with BP control... but 30% heal.
- TBI: Best to avoid brain injury. Neurosurgeons should promptly drain mass lesions. Treating a TBI patient, the ICU team must avoid hypoxia, hypotension.
- Wait about 10 days before tracheostomy in ICU ventilated patients
- The transfusion trigger is ~ 7 g/dL; avoid old blood.
- In patients needing a massive transfusion, 1:1:1 is the ideal tactic for reducing risk of exsanguination.

**William Shakespeare [1564-1616]**

**On needing a surgeon**

“MERCUTIO: Go villain, fetch a surgeon.

ROMEO: Courage, man. The hurt cannot be much.

MERCUTIO: No, 'tis not so deep as a well, nor so wide as a church door; but 'tis enough 'twill serve. Ask for me tomorrow, and you shall find me a grave man.”

*Romeo and Juliet III, i 97*
Thank you!