What I Have Learned
About Glenoid Bone Defects
How to Recognize and Treat

Giuseppe Milano

The Glenoid School

Lesson 1: Glenoid bone defect is an outcome predictor

Shoulder stability in the "midrange of motion" depends on the glenoid osseous profile, not on the status of the soft tissues

**Biomechanics**

**Flat glenoid**
- < resistance to shear stress

**Narrow glenoid**
- < restraint to anterior translation

*Burkhart 2000, Wellmann 2009*

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**Clinical studies**

**Risk factors:**
- Glenoid bone loss
- Humeral head defects
- Hyperlaxity
- Age < 40 ys at first dislocation
- Male sex
- Sport activity level

*Boileau 2008, Porcellini 2009, Filmkiiä 2010, Olds 2015*

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**Clinical studies**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rowe, 1978</td>
<td>73%</td>
</tr>
<tr>
<td>Pavlov, 1985</td>
<td>21%</td>
</tr>
<tr>
<td>Sington, 1987</td>
<td>17%</td>
</tr>
<tr>
<td>Taylor, 1997</td>
<td>22%</td>
</tr>
<tr>
<td>Stevans, 1999</td>
<td>25%</td>
</tr>
<tr>
<td>Sugaya, 2003</td>
<td>90%</td>
</tr>
<tr>
<td>Edwards, 2003</td>
<td>87%</td>
</tr>
<tr>
<td>Boileau, 2006</td>
<td>49%</td>
</tr>
<tr>
<td>Griffith, 2008</td>
<td>71%</td>
</tr>
<tr>
<td>Shaha 2015</td>
<td>89.2%</td>
</tr>
</tbody>
</table>

*Boileau 2006, Shaha 2015*
Clinical studies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Critical size (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bigliani, 1998</td>
<td>25%</td>
</tr>
<tr>
<td>Burkhart, 2000</td>
<td>25%</td>
</tr>
<tr>
<td>Ito, 2000</td>
<td>20%</td>
</tr>
<tr>
<td>Chen, 2005</td>
<td>20%</td>
</tr>
<tr>
<td>Rhee, 2006</td>
<td>20%</td>
</tr>
<tr>
<td>Nanasakopoulos, 2007</td>
<td>27%</td>
</tr>
<tr>
<td>Boileau, 2006</td>
<td>25%</td>
</tr>
<tr>
<td>Molagne, 2007</td>
<td>20-30%</td>
</tr>
<tr>
<td>Ahmed, 2012</td>
<td>25%</td>
</tr>
</tbody>
</table>

Stabilizing mechanism in bone-grafting of a large glenoid defect.

6 mm bone defect = 25% glenoid width

Barchilon VS, Kotz E, Barchilon Ben-Av M, et al.
A simple method for quantitative evaluation of the missing area of the anterior glenoid in anterior instability of the glenohumeral joint.

25% glenoid width = 20% inferior glenoid area
Shaha JS, Cook JB, Song DJ, et al.
Redefining ‘Critical’ Bone Loss in Shoulder Instability
Functional Outcomes Worsen With ‘Subcritical’ Bone Loss.

- Cohort study
- 73 shoulder
- F-U: 48.3 months

“Glenoid bone loss above 13.5% led to a clinically significant decrease in functional outcome scores and increase in failures”

Analysis of risk factors for glenoid bone defect in anterior shoulder instability.

Factors related to the size of glenoid bone defect

<table>
<thead>
<tr>
<th>Factor</th>
<th>P</th>
<th>B</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>0.005</td>
<td>0.015</td>
<td>0.002</td>
<td>0.29</td>
</tr>
<tr>
<td>Number of dislocations</td>
<td>&lt; 0.0001</td>
<td>0.77</td>
<td>0.55</td>
<td>0.99</td>
</tr>
<tr>
<td>Manual work</td>
<td>0.015</td>
<td>2.51</td>
<td>0.50</td>
<td>4.53</td>
</tr>
</tbody>
</table>

Factors related to the presence of critical bone defect (20%)

<table>
<thead>
<tr>
<th>Factor</th>
<th>P</th>
<th>OR</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at first dislocation</td>
<td>0.006</td>
<td>0.03</td>
<td>0.003</td>
<td>0.37</td>
</tr>
<tr>
<td>Number of dislocations</td>
<td>0.01</td>
<td>9.54</td>
<td>1.74</td>
<td>52.47</td>
</tr>
</tbody>
</table>

Humeral head defect

<table>
<thead>
<tr>
<th>Instability</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calandra, 1989</td>
<td>47%</td>
</tr>
<tr>
<td>Hovelius, 1996</td>
<td>54%</td>
</tr>
<tr>
<td>Taylor, 1997</td>
<td>80%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recurrence</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rowe, 1984</td>
<td>76%</td>
</tr>
<tr>
<td>Burkhart, 2000</td>
<td>100%</td>
</tr>
</tbody>
</table>

Combined lesions (glenoid + HH):
- 2-mm glenoid defect + medium Hill Sachs  
  Arthroscopic Bankart
- ≥4-mm glenoid defect + small Hill Sachs  
  could be not enough!

Arciero 2015
Bipolar defects

- Glenoid track concept (cadaveric study)
  Yamamoto 2007

- Glenoid track in vivo (3D Motion analysis, MR)
  Omori 2014

- “On-Track/Off-Track” lesion
  Di Giacomo 2014

Lesson 2: How to recognize a glenoid bone defect


“Arthroscopy significantly overestimates glenoid bone loss compared with CT and call into question its validity as a method of measurement”

Bare spot is not a reliable landmark
Cresswell 2005, Kralinger 2006, Miyatake 2014
**X-rays**

- Standard AP
- Bernageau view
- Grashey view
- West Point view
- Stryker notch
- Scapular Y view
- Garth view
- Didiee view

Edwards 2003, Pansard 2013, Forsythe 2015

**CT scan**

**Diameter-based methods**

- 2D: X index (Gerber 2002)
- 2D: maximum length width (Griffith 2003)
- 3D: AP distance from bare area method (Burkhart 2002, Sugaya 2005)
- 3D: ratio method (Barchilon 2008)
- 3D: glenoid index (Chuang 2008)

**Digital surface area**

- 3D: Circle method (Volume Rendering Technique (VRT)) (Sugaya 2003)
- 2D: PICO method (circle method) (Baudi 2005)

**Mean overestimation error**

- 3.9%±1.9% (range: 0.0%-5.8%)

Glenoid diameter is an inaccurate method for percent glenoid bone loss quantification: analysis and techniques for improved accuracy. Arthroscopy. 2015 Apr;31(4):608-614.
Comparison between 2D and 3D computed tomography evaluation of glenoid bone defect in unilateral anterior gleno-humeral instability.

- Cohort study
- 100 patients
- Unilateral instability

<table>
<thead>
<tr>
<th>2D-3D agreement</th>
<th>Mean value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean difference</td>
<td>-0.62%</td>
<td>0.29 - 0.92</td>
</tr>
<tr>
<td>Upper limit</td>
<td>4.54%</td>
<td>3.98 - 5.1</td>
</tr>
<tr>
<td>Lower limit</td>
<td>-3.30%</td>
<td>-2.74 - -2.92</td>
</tr>
</tbody>
</table>

CT scan

Bilateral exam
Griffith 2003, Sugaya 2003, Baudi 2005

- Unsuitable in bilateral instability
- Risk related to radiation exposure!!

Analysis of agreement between computed tomography measurements of glenoid bone defects in anterior shoulder instability with and without comparison with the contralateral shoulder
Accepted by AJSM

<table>
<thead>
<tr>
<th>Glenoid bone defect</th>
<th>Bilateral 2D</th>
<th>Unilateral 2D</th>
<th>Bilateral 3D</th>
<th>Unilateral 3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap of the defect</td>
<td>4.7 ± 0.3 (0.5)</td>
<td>5 ± 0.2 (0.3-0.8)</td>
<td>4.4 ± 0.3 (0.2)</td>
<td>4.5 ± 0.2 (0.3)</td>
</tr>
<tr>
<td>Mean difference (95% CI)</td>
<td>0.64% ± 2.3% (0.0; 5.3)</td>
<td>0.60% ± 2.6% (0.0; 5.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of the defect</td>
<td>Yes</td>
<td>64/100</td>
<td>61/100</td>
<td>61/100</td>
</tr>
<tr>
<td>No</td>
<td>36/100</td>
<td>39/100</td>
<td>39/100</td>
<td>39/100</td>
</tr>
<tr>
<td>Percent agreement</td>
<td>93% (k=0.9) (p&lt;0.001)</td>
<td>93% (k=0.9) (p&lt;0.001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of defect</td>
<td>Absent</td>
<td>36/100</td>
<td>30/100</td>
<td>30/100</td>
</tr>
<tr>
<td>Bone erosion</td>
<td>54/100</td>
<td>51/100</td>
<td>51/100</td>
<td>51/100</td>
</tr>
<tr>
<td>Bony Bankart lesion</td>
<td>101/100</td>
<td>101/100</td>
<td>101/100</td>
<td>101/100</td>
</tr>
<tr>
<td>Percent agreement</td>
<td>93% (k=0.9) (p&lt;0.001)</td>
<td>93% (k=0.9) (p&lt;0.001)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MRI

2D MR:
- Circle method (Sugaya 2003)

3D MR:
- Circle method (Sugaya 2003)
- AP distance from bare area method (Sugaya 2005)

3D MRA:
- AP distance from bare area method (Sugaya 2005)

Advantages of MR:
- No radiation exposure
- Evaluation of soft tissue lesions

Agreement CT- MR: controversial!
- High correlation
  Tian 2012, Lee 2013, Stecco 2013, Markenstein 2014
- 3D CT is the most accurate and reliable imaging modality for predicting glenoid bone loss
  Bishop 2013, Renko 2013, Sugaya 2014

Humeral head defect

<table>
<thead>
<tr>
<th>Authors</th>
<th>Critical size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gerber, 1995</td>
<td>40%</td>
</tr>
<tr>
<td>Miniaci, 2004</td>
<td>25%</td>
</tr>
<tr>
<td>Cham, 2005</td>
<td>20%</td>
</tr>
<tr>
<td>Millot, 2005</td>
<td>20% - 30%</td>
</tr>
<tr>
<td>Buck, 2007</td>
<td>30%</td>
</tr>
<tr>
<td>Raiss, 2008</td>
<td>21%</td>
</tr>
</tbody>
</table>

- Biomechanical studies:
  - Sekiya 2003: > 25%
  - Kaar 2010: 5/8 of the radius (38%)

No universally accepted method to quantify the lesion!!!
**Humeral head defect**

- 40 pts, bilateral CT scan
- M1: \( \frac{\text{Vol healthy HH} - \text{Vol affected HH}}{\text{Vol healthy HH}} \times 100 \)
- M2: \( \frac{\text{Vol virtual fragment}}{\text{Vol healthy HH}} \times 100 \)

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Method</th>
<th>ICC</th>
<th>95% CI Low</th>
<th>95% CI Upp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-observer</td>
<td>M1</td>
<td>0.99</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>0.99</td>
<td>0.96</td>
<td>0.99</td>
</tr>
<tr>
<td>Inter-observer</td>
<td>M1</td>
<td>0.93</td>
<td>0.88</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>0.85</td>
<td>0.73</td>
<td>0.92</td>
</tr>
</tbody>
</table>

**Lesson 3: How to treat a glenoid bone defect**

**Treatment algorithm**

<table>
<thead>
<tr>
<th>Glenoid defect</th>
<th>Hill Sachs lesion</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20%</td>
<td>Small (on-track)</td>
<td>Arthroscopic Bankart repair</td>
</tr>
<tr>
<td>&lt;20%</td>
<td>Medium (off-track)</td>
<td>Arthroscopic Bankart repair + remplissage</td>
</tr>
<tr>
<td>≥20%</td>
<td>Small (on-track)</td>
<td>Latarjet / bone augmentation</td>
</tr>
<tr>
<td>≥20%</td>
<td>Medium/large (off-track)</td>
<td>Latarjet + remplissage / HH bone graft</td>
</tr>
</tbody>
</table>
Latarjet

Rationale

- Glenoidoplasty effect (Walch 2000, Yamamoto 2010)
- "Sling effect" (conjoined tendon)
- Capsular reinforcement (CAL)
- 2-3 suture anchors between graft and glenoid
  - Extra-articular graft (< HH abrasion) (Burkhart 2007, Boileau 2014)

Latarjet failure

- Technical errors: try to get it right at first time!!!
- Capsular hyperlaxity (Boileau 2009): open capsular shift
- Glenoid bone defect > 30% (Provencher 2010): bone graft
- Large Hill-Sachs: it must be assessed before surgery (?)

Congruent arc Latarjet

- Coracoid rotation: improves radius of curvature
  
  De Beer 2010, Boons 2013, Noonan 2014
- Significantly poorer fixation stability (vs classic Latarjet)
  
  Giles 2013
Autologous bone graft

**Iliac crest (bi- or tricortical)**


- Donor site morbidity
- Results similar to Latarjet
- Higher risk of recurrence and OA

*Longo 2014

OC Allografts

- Glenoid, iliac crest, distal tibia


- **Pros:**
  - No donor site morbidity
  - Articular cartilage surface restoration (width – depth)
  - No graft resorption
  - Excellent clinical outcomes *(Sayegh 2014)*

- **Cons:**
  - Limited availability (high costs)
  - Cryopreservation may undermine the tissue viability

*Zhao 2014

Is there a role for arthroscopy?

**Bony Bankart repair**

- Suture anchors *(Sugaya 2005, 2006, Porcellini 2007)*
- *Bony Bankart Bridge technique* *(Millet 2009, 2013)*

**Pros:**
- Intra-articular control of reduction
- Limited trauma to soft tissue

**Cons:**
- Poor fixation strength
- Poor outcome in chronic injuries
Is there a role for arthroscopy?

**Arthro-Latarjet (+ Bankart repair)**

- Recurrence rate: as low as for open Latarjet
  

- No comparative studies with open Latarjet/bone block

- Technically demanding with a steep learning curve

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**Is there a role for arthroscopy?**

**Bone graft**

- Acromion (Mochizuchi 2007)

- Iliac crest
  - Screws (Scheibel 2008)
  - Buttons (Taverna 2014)

- Distal clavicle (Tokish 2014)
  - Risk of AC joint instability (Beitzel 2012)

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- High prevalence of bone defects
- Glenoid: CT (area measurement)
- No universal method for Hill-Sachs
- Many surgical options:
  - Bone defect-based algorithm
  - Surgeon’s experience!
Thank you!