Lead Poisoning From Intracorporeal Bullets

Toxic Aspects of Ammunition

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Disclosures

- I have never shot anyone
- I have not been shot
- I have no intracorporeal bullets (ICB) in me (of which I am aware)
- I was held up at gunpoint while repaying my USPHS scholarship obligation
Educational Goals

- Describe incidence/epidemiology of Pb poisoning from intracorporeal bullets (ICB)
- Identify risk factors for Pb poisoning by ICB
- List the indications for chelation
- List the indications for ICB removal
Acute Lead Poisoning:

- Paint chips
- Jewelry
- Toys
- Candy
- Lead Pottery
- Glazes
Hyper-acute Lead Poisoning
Hyper-acute Lead Poisoning

"HEY, I MADE A HOLE IN JUAN."

Hands: CARTOONSTOCK.com

Search ID: hbrn1241
H. Brown
Incidence of ICB & Plumbism

- Due to long hx of Pb in ammunition, incidence of ICB is likely high, but is unknown

- ICBs common: 84,258 nonfatal GSW injuries 2013

- Incidence of plumbism (saturnism) with ICB also unknown

- Most persons with ICB likely asymptomatic
Plumbism from ICB

- First reported in literature in 1867
- Dozens of reports in literature since then
- Due to 230 GSW/day in USA, it is probably underdiagnosed

- Reports indicate wide variability in:
  - Time from injury to onset of clinical symptoms
  - Degree of Pb exposure/absorption
  - Severity of Pb toxicity
Plumbism from ICB

- Due to the non-specific symptoms of chronic Pb poisoning, their cause is often misdiagnosed

- Without history or radiography, clinical suspicion may remain low
Machle et al. 1940

- Reviewed 40 published cases of plumbism 2º ICB
- Reviewed criteria for the diagnosis of lead poisoning:
  - BLL
  - Other lab abnormalities (anemia, baso. stippling)
  - Corresponding signs and symptoms consistent with lead poisoning
- Plumbism Sx started 8 days- 40 years after GSW
- Only 8-10 satisfied contemporary definition of lead poisoning
Historical “Normal” BLL USA

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Delay to Plumbism Since Machle

- Elevated BLL begins from 2 months to 52 years after initial injury
- Time to onset of elevated BLL seems correlated to the form of the Pb ICB
  - Retained single-lead bullets: 20 to 40 years (mean 17 years)
  - Shrapnel: average 10 years
  - Retained birdshot: 2 days- 2 years (mean 8 mo.)
- Difference may be $2^\circ$ lead surface areas exposed to physiologic fluids
Sought to determine if patients with ICB have elevated BLL regardless of location in body

Case control study of ICB in ED setting

Cases: 15 ED patients with co-incidental ICB on x-ray

Controls: 15 age, sex, race & zip code matched ED pts.

Occupational history obtained to rule-out workplace lead exposures
Results of BLL Testing

Cases with ICB:
- Mean BLL ± SD was 17 ± 9.78 µg/dL
  - 0.8211 µmol/L ± 0.472 µmol/L
  - Range 7-50 µg/dL (0.338- 2.415 µmol/L)

Controls- no ICB:
- Mean BLL ± SD was 7 ± 3.77 µg/dL
  - 0.338 ± 0.182 µmol/L
  - Range 0- 16 µg/dL (0- 0.773 µmol/L)

Farrell, et al 1999
Results

- Case subjects had following Sx > 1 month:
  - headaches, malaise, extremity weakness, paresthesias, and gastrointestinal disturbances.

- Most case subjects also had PMH of:
  - hypertension, cerebrovascular disease, ethanol abuse, and seizure disorders.

Farrell, et al 1999
Pb ICB in Soft Tissues

- Become enveloped in a fibrous capsule and become isolated from surrounding tissues
  - Thought to undergo minimal degradation
  - Pb absorption \textit{should be} negligible

- ICB in joints or in close proximity to synovial membranes will dissolve Pb

- ICB in close proximity to well-vascularized cystic structures can dissolve Pb & cause absorption

Farrell, et al 1999
Unanswered Questions

- Do asymptomatic patients with ICB need to be followed?
  - If so, for how long?
- Can the rate of Pb dissolution from ICB not in contact with a synovium be determined?
  - Does it need to be determined?
- What is the natural course of the retained Pb in these patients?

Farrell, et al 1999
Systematic review of the literature
  - Is ICB removal from pelvis or extremities routinely indicated?
  - If not, then what are the indications for removal of ICB in pelvis/extremities?

Boolean Medline search:
  - (bullet OR gunshot) AND (retained OR removal)

Also searched bibliography of references
Graded by level of evidence 1-5
## Levels of Evidence

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Results

- 567 articles produced initially
  - Excluded those not addressing the question
    - 55 remained (<10%)
  - Then excluded expert opinion, case reports, and editorials (level V evidence)
    - 7 remained (1.2%)
  - Search of biblios yielded 1 additional study
    - 8 total were reviewed in total
      - 7 were level 5 studies
      - 1 level 3 retrospective with control

Riehl et al. 2013 Clin Orth Rel Res
Evidence Supporting ICB Removal

- No clear evidence supporting ICB removal
- One Level 3 study looking at infection as main outcome (not plumbism)
  - 34 of 47 GSW victims had retained ICB
  - 1 of 33 developed infection (trochanteric bursa) requiring removal
  - None with GI penetration developed infection
  - Authors concluded ICB not needed to prevent infection

Riehl et al 2013 *Clin Orth Rel Res*
Level IV Evidence Supporting ICB Removal

- Evidence supporting delayed removal if lead poisoning occurs- one study

- There was evidence supporting immediate ICB removal when in joint (6 studies) and palm of hand & sole of foot

- Evidence for delayed removal due to pain at ICB (1 study)

Riehl et al 2013 Clin Orth Rel Res
Prospective cohort study- 28 acute GSW victims with ICB
- No control group

Initial BLL drawn @ admission or within 6 mo., & occ/env history of Pb exposure

28 patients had 2nd BLL drawn 5- 238 days later

Geom mean BLL went from 5.1 µg/dL (range 0.8 to 42.5 µg/dL) to 7.7 µg/dL (range of 2.3 to 50.0 µg/dL)

Increase BLL associated with bone fx
Dienstknecht et al

Eur J Trauma Emerg Surg 2012

- Comprehensive literature review in 2011
- Search terms: “bullet,” “fragment removal,” “gunshot,” “gunshot wounds,” “firearm,” “missile,” and “missile wounds.”
- Search of Medline, EMBASE, and the Cochrane Central Register
- Articles in English and German were included
Dienstknecht et al

Eur J Trauma Emerg Surg 2012

- 5,000 articles originally identified
- 145 relevant by title and abstract review
- Only 6 remained - all retrospective
- Few clear indications for ICB removal were found
Dienstknecht et al

Eur J Trauma Emerg Surg 2012

- Remove ICB when:
  - In joints, CSF, pleural fluid, or the globe of the eye
  - ICB impingement on a nerve or root
  - ICB within the lumen of a vessel (risk of ischemia or embolization)
  - Lead poisoning
  - Fragment needed for forensic reasons
ICB in Articular Spaces

- Synovial fluid is an excellent solvent for exposed lead due to its pH and the presence of hyaluronic acid.

- Animal and in-vitro models have demonstrated enhanced dissolution of Pb in synovial fluid.

- Most literature recommends ICB removal & debridement of affected tissues when ICB in joint spaces.
Factors Contributing to Pb Dissolution in Articular Spaces

- When large surface area of lead is available for solubilization- buckshot or shattered fragments
- ICB in mobile or weight-bearing joints
- Chronic inflammation of the joint with resultant arthritis
- Enhanced lymphatic and vascular drainage of solubilized lead.
Causes of Plumbism from Pb ICB

- Patients with chronic Pb exposure may develop enhanced Pb absorption and subsequent overt toxicity
  - After re-injury to an area with Pb ICB
  - During periods of hypermetabolic states,
    - Metabolic acidosis
    - Hyperthyroidism
    - Pregnancy & lactation
    - Febrile illnesses
  - After prolonged immobilization & bone resorption
Causes of Plumbism from Pb ICB

- Mobilization of pools of stored Pb due to alteration in the normal balance of osteoblast and osteoclast function
- Mobile Pb stores in bone cause elevated BLL and acute plumbism due to this sudden bolus.
- Rx with Pb chelation & surgical removal of ICB when possible
Causes of Plumbism from ICB

- Risk increased when ICB in contact with acidic fluid- speeds Pb dissolution
  - Synovial fluid
  - Cerebrospinal fluid
  - Pleural fluid

- Other high risk areas:
  - Bone, especially when fractured by fragment
  - Soft tissues initially until fibroosed/contained

- Risk also said to be dependent on surface area of fragments- worse with birdshot
Be Alert for the Vague Sx of Chronic Plumbism

- Enhanced awareness of Sx in patients with history of GSW/ICB
  - Headache
  - Mental status changes
  - Abdominal colic
  - Renal insufficiency
  - Impotence
  - Neurologic Sx
Laboratory Evidence of Chronic Plumbism

- Laboratory tests
  - BLL
  - Unexplained anemia, especially hypochromic, microcytic anemia
  - Basophilic stippling
  - ZPP (FEP)

- Exam findings: Burton’s line; Pb lines (bone)
A 61-year-old man presented for evaluation of increasing abdominal pain of eight months' duration.
A 61-year-old man presented for evaluation of increasing abdominal pain of eight months' duration.
Suggested Rational
Recommendations

- RCT will not get IRB approval
- Remove ICBs from joints (all types)
  - Don’t forget bursae
- Remove ICBs acutely from CSF & pleural contact if surgery otherwise indicated due to injury
  - ? peritoneal
- Chelate before & after removal for a period of time
Suggested Rational Recommendations

- Baseline BLL in soft tissue ICB, follow for elevation (or migration of fragment)
  - May be unrecognized that ICB is in bursa
  - Presence of fracture increases risk of BLL elevation
- Make patient aware of future plumbism risk
- Cyclical chelation may be needed for ICB that cannot be removed (pleural, peritoneal)- numerous anecdotal reports
Bibliography


