Extracorporeal Shock Wave Lithotripsy in Children

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The International Society of Nephrology (ISN) is a global not-for-profit society dedicated to improving kidney care and reducing the incidence and impact of kidney disease worldwide.

Through its global network and programs, ISN brings together the developing and developed worlds in a collaborative effort in fighting and treating kidney disease on a global scale.

- Established in 1960
- 9,000 professional members from 129 countries
- Collaborating with over 70 national and regional societies around the world

Visit us at www.theisn.org
ISN – The Scientific Society

Meetings

ISN World Congress of Nephrology is the leading biennial educational event in international nephrology
Next Congress: Sustainability & Diversity - March 13-17, 2015, Cape Town
www.wcn2015.org

ISN Nexus Symposia bridge the gap between basic research and clinical practice
Next Symposia:
• Hypertension and the Kidney - September 25-28, 2014, Brisbane, Australia
www.isnnexus.org

ISN Forefronts Symposia focus on emerging and groundbreaking research
Next Symposia:
• Genetic Basis of Renal Disease - September 11-14, 2014, Boston (MA), USA
www.isnforefronts.org

Advancing Nephrology around the World
ISN – The Scientific Society

ISN Education

ISN Education is a comprehensive collection of educational resources with a database of articles, case studies, guidelines, presentations, and images. www.theisn.org/education

Publications

Kidney International (KI), ISN’s official journal, is one of the most cited in nephrology and widely regarded as the world’s premier journal on the development and consequences of kidney disease. www.nature.com/ki

Nature Reviews Nephrology, an official publication of ISN, is a peer-reviewed journal for nephrologists and affiliated healthcare professionals. www.nature.com/nrneph
The Sister Renal Centers Program (SRC) links renal centers in emerging countries with supporting centers of excellence in the developed world. With this educational support and guidance, self-sufficient renal centers are created in emerging countries.
Application Deadline: September 15

The Fellowship Program helps educate physicians coming from emerging economies, giving them hands-on training opportunities unavailable in their home nations.
Application Deadlines: December 15 and June 15

The Continuing Medical Education Program (CME) brings essential teaching and training to some 14,000 doctors in over 40 settings every year. CME meetings take place in the developing world, where expert speakers from the developing and the developed world share their knowledge and experience in clinical care and research.
Applications: Throughout the year
ISN – The Outreach Society

ISN Capacity Building Programs

The Educational Ambassadors Program sends experts to developing renal centers for one to four weeks to provide hands-on training or help develop new services, community-based research or screening programs.

Application Deadlines for Institutions: May 1 and October 1

The Clinical Research and Prevention Program aims in part to educate people in developing countries about the importance of having healthy kidneys. Many of the projects funded through the program set up screening and education to raise awareness and improve the understanding of kidney disease.

Application Deadlines: April 1 and October 1

These and other ISN programs work together to vastly improve standards of renal care in less developed countries. ISN members contribute to and lend support to the educational and humanitarian work needed to further advance kidney care worldwide.
World Kidney Day (WKD), a joint initiative of the ISN and the International Federation of Kidney Foundations (IFKF) informs and educates health policy-makers, medical staff, and the general public worldwide about chronic kidney disease to drive the earliest possible diagnosis and optimal treatment.

www.worldkidneyday.org

The recently launched Saving Young Lives Project offers realistic, collaborative, sustainable and better care opportunities for low-resource health settings to look after AKI patients. A partnership between International Society of Nephrology (ISN), International Pediatric Nephrology Association (IPNA), International Society for Peritoneal Dialysis (ISPD) and Sustainable Kidney Care Foundation (SKCF).
ISN Programs CME Supported Speakers

ALANEPE (Asociación Latinoamericana de Nefrología Pediatrica) and ACONPEPE ( Asociación Colombiana de Nefrología Pediatrica )

- Dr. Ron Shapiro (Colombia)
- Dr. Carlos Estrada (Colombia)

The Travel expenses of the ISN Speakers for this meeting are supported by an unrestricted educational grant of F. Hoffmann-La Roche”.

Topics to Cover

• Stones
• Shock Wave Lithotripsy – Background & History
• SWL – Use in Children
• SWL – Outcomes, Risks
• SWL – Patient Selection
Kidney Stones

• 1/3000 pediatric admissions in the US (about 2% of all stone disease)
• Boys = girls
• Mean age: 5-7 years
• Higher prevalence in Caucasians
• ? Increasing incidence
• “Stone Belt”
  – Deep South in North America
Kidney Stones

- 45-65% calcium oxalate
- 14-30% calcium phosphate
- 13% struvite
- 5% cystine
- 4% uric acid
- 1/3 of pediatric/adolescent stone patients will have an anatomic anomaly of the GU tract
Kidney Stones

• Pediatric ureter is at least as compliant as the adult ureter
• <4 mm: >80% passage
• 4-6 mm: 50% passage
• >6 mm: <5% passage

**TABLE 3: CHANCE OF PASSING URETERAL STONES**

<table>
<thead>
<tr>
<th>Stone size (mm)</th>
<th>Number of days to pass stone (mean)</th>
<th>% Likelihood of eventual need for intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 or less</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>4-6</td>
<td>22</td>
<td>50</td>
</tr>
<tr>
<td>&gt;6</td>
<td>--</td>
<td>99%</td>
</tr>
</tbody>
</table>
Shock Wave Lithotripsy

- Developed in Germany in 1970’s (Dornier Corp)
- Initial human trials in early 1980’s
  - First human treatment February 1980
- Used in children by mid-1980’s
  - Delay in pediatric utilization due to concern over long-term effects
Shock Wave Lithotripsy

• Numerous different designs and companies

• Basic principles
  • Generator – device to create shock waves
  • Focus – concentrate the shock waves on a target zone
  • Couple – allow propagation of shock waves into the patient
  • Localize – image stone and place it into the target zone
Electrohydraulic

Electromagnetic

Piezoelectric
Shock Wave Lithotripsy
SWL Literature - Challenges

• Define “Stone-free”, please
  – Imaging modality
  – Number and size of stone
  – “Clinically significant” residual stones
  – Retreatment rates

• Technology creep
  – By the time reports of outcomes are published, the equipment used is obsolete

• Technique details
  – Number of shocks, rate of shock, imaging mode
Pediatric SWL – is it different than in adults?

• Hypothesized differences
  – Children pass stone fragments more easily
  – Stones in children fragment more easily
  – Less tissue between coupling medium and stone
  – Localization of stones is easier in children due to smaller body size
  – Developing kidney or other structures more susceptible to shock-wave induced injury
Pediatric SWL – is it different than in adults?

- Kurien (2009) compared results in adults and children
  - Stone free, retreatment, complication rates similar
  - Fewer shocks and lower energy settings for children
Historical SWL in children

• First reports in late 1980’s
  – Newman et al 1986
  – Sigman et al 1987
  – Frick et al. 1988

• Success rates of 85%++
  – Many papers report success rates of 100%
Outcomes – early era

• Dornier HM-3
• 1986-1989
  – Compilation of 7 studies*
  – 194 patients with outcome data
  – 155 “stone free” – 80%
  – Range of 70-92%
  – Retreatment rates from 8-40%

Outcomes – recent era

- Myers 1995
  - 445 children on Siemens Lithostar (electromagnetic)
  - 68% stone free, retreatment 14%

- Aksoy 2004
  - 129 children on Dornier MPL-9000 (electrohydraulic)
  - 86-90% stone free
Outcomes – recent era

• Defoor 2005
  – 88 children Dornier Compact Delta (electromagnetic)
  – 68% stone free (74% after 2 treatments)
Outcomes – Anatomic factors

• Less successful in setting of anatomic or functional urological conditions

• Nelson 2008
  – 13% vs 67% stone free with and without anatomic risk factors

• Tan 2004
  – 32% vs. 65% stone free with and without anatomic risk factors
Outcomes – Infants

• Lottmann 2000
  – 19 infants (5-24 mos)
  – Technomed Sonolith or Direx Nova (electrohydraulic)
  – 53% stone free (95% after 2 sessions)

• Shukla 2001
  – 8 premature infants (9-15 mos, all born <32 weeks)
  – Dornier HM3 (electrohydraulic)
  – 100% stone free
### Outcomes – Infants

**McLorie 2003**
- 34 infants (6-40 mos)
- Dornier HM3 or MFL5000 (electrohydraulic)
- 66% success (86% multiple treatments)
- No major complications

**Ramakrishnan 2007**
- 74 infants (3-24 mos)
- Wolf Piezolith (piezoelectric)
- 88% stone free
- Obstruction and/or UTI in 7 (5%)
- Retreatment in 35%
Outcomes – Large Stones

• Shouman 2009 (Dornier DoLi S)
  – 24 children (2-14 yrs)
  – Stones >25 mm (mean 31mm)
  – 83% stone free
  – 4 steinstrasse, 2 colic (1 hospitalized)

• Orsola 1999 (Siemens Lithostar)
  – 15 children with staghorn stones
  – 73% stone free after 1 or more sessions
  – 1 post-op fever

• Al-Busaidy 2003 (Wolf Piezolith)
  – 42 children with staghorn stones
  – Stone free 79%
  – Stented patients had fewer complications (0% vs 21%)
Acute complications after pediatric SWL

- Meta-analysis of complications in 1866 SWL patients (D’Addessi 2008)

Table 3: Number, percentage, and type of the most frequent complications reported

<table>
<thead>
<tr>
<th>Type of complication</th>
<th>Complications, total of patients = 1866 (n [%])</th>
<th>Complications, total of complications = 336 (n [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematuria</td>
<td>150 (8.03)</td>
<td>150 (44.6)</td>
</tr>
<tr>
<td>Steinstrasse</td>
<td>31 (1.6)</td>
<td>31 (9.2)</td>
</tr>
<tr>
<td>Infection with fever</td>
<td>25 (1.3)</td>
<td>25 (7.4)</td>
</tr>
<tr>
<td>Infection without fever</td>
<td>15 (0.8)</td>
<td>16 (4.7)</td>
</tr>
<tr>
<td>Obstruction</td>
<td>13 (0.9)</td>
<td>18 (5.4)</td>
</tr>
<tr>
<td>Colic</td>
<td>57 (3)</td>
<td>57 (17)</td>
</tr>
<tr>
<td>Other complications</td>
<td>39 (2)</td>
<td>39 (11)</td>
</tr>
<tr>
<td>Renal hematoma</td>
<td>7 (0.3)</td>
<td>7 (2)</td>
</tr>
</tbody>
</table>
Long term renal effects of SWL

- Extensive investigations of adverse renal effects of SWL – stay tuned!
  - Tubular atrophy
  - Thickening of Gerota’s fascia
  - Renal fibrosis
  - Decreased renal plasma flow, glomerular filtration
  - Hypertension, proteinuria
Long term renal effects of SWL

• But – is the effect different (worse) in the pediatric population?
• Renal development (maximal GFR) complete by age 2
  – Kidneys in most children undergoing SWL are largely “mature”
• Young kidneys more susceptible to scarring after inflammation
Effects of SWL on developing kidney - negative

- Infant vs. adult (monkey SWL model)
  - RPF decreased, plasma renin increased more in infants (Neal 1991)

- Infant vs. adult (rabbit SWL model)
  - Greater rise in arterial blood pressure at 4, 8 weeks among immature animals (Feagins 1991)

- Infant vs. adult (rat SWL model)
  - Immature rats exposed to SWL had changes in renal function and histology (but normal body and renal growth). (Claro Jde 1994)
Effects of SWL on developing kidney - negative

- 29 children with 9 year follow-up after SWL (HM-3) (Lifshitz 1998)
  - Normal renal function at follow-up
  - 1 patient with hypertension
  - Compared renal size to expected size for age
  - Found decreased renal length vs. expected in treated kidneys
Effects of SWL on developing kidney - negative

- Tubular dysfunction after SWL in pediatric kidneys (Villanyi 2001)
  - Serial measurements of serum and renal metabolites after SWL
  - No change in serum/urine electrolytes
  - Increase in aspartate transaminase, alkaline phosphatase, LDH, and beta 2-microglobulin
  - Indicator of proximal tubule dysfunction, cell death
- Returned to baseline by 15 days
Effects of SWL on developing kidney – positive

- 9 children undergoing SWL (Wadhwa 2007)
  - GFR and renal scan at 3 and 6 months
  - No change in GFR
  - No new scars on DMSA
  - No hypertension or proteinuria

- 50 children 2-12 years (Goel 1996)
  - No change in GFR at 32 months
Effects of SWL on developing kidney – positive

• 12 out of 50 children age 0-14 yrs had pre- and post-SWL DMSA (Picramenos 1996)
  – No changes seen

• 39 children age 0-17 yrs had pre- and post-SWL DMSA (Traxer 1999)
  – No changes seen
Effects of SWL on developing kidney – positive

- 60 children (age 0-14 yrs) had pre- and post-SWL serum creatinine (Ather 2003)
  - No change noted

- 12 children followed for 3 years for renal plasma flow and body height (Thomas 1992)
  - No abnormalities noted
Pediatric SWL – adjacent organ effects

• Potential for lung injury long recognized
• Experimental data in rats shows massive vascular & alveolar rupture from single thoracic treatment
• In children the lungs are more proximate to the kidneys
  – Esp. for upper pole stones
• The large F2 and high power of the Dornier HM-3 was of particular concern
Pediatric SWL – adjacent organ effects

Most early series found low rates of acute lung injury in practice

– Kroovand 1987 – 2/18 patients (both with scoliosis) had hemoptysis – recovered

– Kramolowsky 1987 – 1/14 patients had pulmonary edema – recovered (shielded with polystyrene)

– Lottman 2000 – 1/19 patients had hemoptysis – recovered (shielded with foam)
Un-gated Pediatric SWL

• Un-gated SWL is associated with cardiac arrhythmias in adults – what about kids?
• Rhee 2006
  – 8 children, 10 sessions
  – No cardiac arrhythmias
  – No conversions to gated SWL
• Shouman 2009
  – 37 children, 69 sessions
  – No cardiac arrhythmias
  – No conversions to gated SWL
SWL – Who is the Appropriate Patient?

• Stone composition
  – Cystine stones are very hard and not responsive to SWL

• Stone size
  – <2 cm generally treatable with SWL

• Stone location
  – Renal
    – Lower pole stone clearance significantly worse; <1 cm in lower pole probably appropriate for SWL
Other Options?

- Percutaneous nephrolithotomy (PNL)
- PNL + SWL
- Ureteroscopy with laser lithotripsy
  - ? Gold standard; ? Replacing SWL?
Summary

• SWL in children results in stone-free rates of 60-80% with contemporary equipment

• Complication rates appear to be very low, although long-term risks remain unclear

• Despite advances in endoscopic equipment, SWL continues to be an excellent option in children without anatomic defects & appropriate stones
Gracias!

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