High Speed Digital Imaging: Clinical & Research Implications

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Talk Outline
- Laryngeal imaging
- Instrumentation
  - High Speed Digital Imaging
  - Kymography
- Current Research
  - Clinical applications
  - Basic science
- Case Examples

Laryngeal imaging
Looking at the vocal folds

Endoscopy
Stroboscopy

Assessment of Dysphonia
- Assessment of vocal fold structure
- Assessment of vocal fold function

Correlating structure with function
- Histological layers vibrate as 2 structures
  - Body: Vocalis
  - Cover: Epithelium and Lamina Propria
- Biomechanical structure 2 layers
  - Active [Body]
  - Passive [Cover]
Laryngeal Imaging

- High Speed Films
- Stroboscopy
- High Speed Digital Imaging (HSDI)
  Digital Kymography (Wittenberg et al, 1997)
- Kymography
  Video Kymography (Švec et al, 1996)

Assessment of function

- Stroboscopy a current gold standard
- But...
  Produces apparent motion

Stroboscopy: Principle

- Stroboscopy produces an optical illusion of several segments of different cycles
- In contrast to continuous light, the stroboscopic light emits rapid pulses
- These illuminated points are fused together to provide an average vibratory pattern

Stroboscopy Drawbacks

- Pitch tracking errors
- Blurred images in disorders, because of pitch tracking problems
- Aphonic patients strobe light not useful, as no movement will be observed
Stroboscopy Drawbacks

- Pitch tracking errors

High Speed Digital Imaging

Instrumentation

- Temporal resolution of up to 4000 fps
- Spatial resolution 512 x 256 pixels
- Both color and black/white recordings
- Simultaneous acoustic and EGG recordings
- Xenon light source of 300 watts required
- Rigid endoscope (70° or 90°)

2002 2004 2008

Clinical HSDI

Indications

- Unexplained hoarseness on stroboscopy
  - 62% unexplainable findings (n = 126, 252 films)
  - 55% unexplainable findings (n = 162, 324 films)
- Moderate & Severe hoarseness
  - 100% (41/41) subjects with severe hoarseness
  - 64% (38/59) subjects with moderate hoarseness
- Vocal Pathologies
  - Neuromuscular (74%)
  - Epithelial (58%)
  - Subepithelial (53%)

Clinical HSDI

Indications

- New insights into the post operative cycle-to-cycle variations in tissue vibratory function following treatment of early glottic carcinoma
  - 0.87% jitter
  - 4.4% shimmer
  - SNR less than 15.4dB

- Differentiating adductor spasmodic dysphonia from muscle tension dysphonia
  - Mehta et al, 2010
  - Patel et al, 2011
Clinical HSDI

Indications
- Observing transient phenomenon
  - Voice onset and offset (Wittenberg et al., 1995)
  - Glissando (Hoppe et al., 2003)
  - Diplophonia (Kiritani et al., 1993)
  - Tremor (Hertegård et al., 2003)
- Monitoring outcomes in voice therapy (Patel, Pickering, Stemple, 2012)
- Assessment of children (Patel, Dixon, Richmond, Donohue, 2012)

Interpretation of HSDI
- Vibratory features rank ordered
  - Vertical level (0% - 3%)
  - Vocal fold edge (16% - 29%)
  - Glottal closure (38% - 52%)
  - Phase closure (56% - 63%)
- Glottal cycle aperiodicities

Voice-Vibratory Assessment and Laryngeal Imaging (VALI)

HSDI: Quantitative Analysis

High speed glottogram

Glottal Cycle Montage
HSDI: Quantitative Analysis

Edge Detect

GAW

Phonovibrogram Computation

Phonovibrogram Computation

PVG Visualization

PVG Visualization
PVG Visualization

Case examples: HSDI

Normal

Voice Onset & Offset

Muscle tension Dysphonia

Pre Therapy

Stroboscopy  High Speed  Motion Analysis

Muscle tension Dysphonia

Post Therapy

Stroboscopy  High Speed  Motion Analysis
Muscle tension Dysphonia

Pressed Vocal Fry

Spasmodic Dysphonia

Strobe
High Speed

Adductor Spasmodic Dysphonia

Strobe
High Speed

Vocal fold cyst

Pseudocyst

Typical Phonation
Inhalation Phonation
Measurement of Treatment Outcomes

Granuloma

Strobe

High Speed

Voice Break: Glissando

Pediatric Voice Assessment

10 year old

Glottal Cycle Montage

76.57% children (5-10 years) posterior gap (Patel et al, 2011, Int. J. of Pediatric ORL)

VF closure more shutter-like, opening zipper-like (Döllinger et al, 2011, Laryngoscope)
Quantifying Vocal Development

- Vibratory Amplitude
- Membranous to Cartilage Length

Vocal Nodules: 10 year old

HSDI Limitations

- More powerful light
- Recording duration limited to 4-6 seconds
- Sound playback not simultaneous with video
- Rigid endoscopy only
- Large data storage files
- Limited normative & disordered data

Kymography

- Kymograph is a spatio – temporal image that show a fixed horizontal line in the vocal fold image over time
Kymography

Videokymography (Švec et al., 1996)

Digital kymography (Wittenberg et al., 1997)

Interpretation of Kymograph

- Cycle-to-cycle variability
- Right-left asymmetry
- Presence, type and extent of mucosal wave
- Open phase features
- Closed phase features
- Ventricular fold motion

Kymography

Applications

- Extent of mucosal wave propagation
- Visibility of upper and lower margins of vocal folds
- Assessing opening and closing phases
- Detecting ventricular phonation

Kymographic Patterns

Normal

High Pitch

Loud

Vocal Fry

MTD
Kymographic Patterns

Right vocal fold paralysis

Kymography

• Advantages
  • Less expensive
  • Less data stored & processed
  • Recording duration unlimited
  • Good spatial resolution (768 pixels)
  • Good temporal resolution (7812.5 images/sec)
  • Extreme vocal performance

• Disadvantages
  • Documentation on videotape / photograph tedious
  • Distortion of spatial information if scope not perpendicular
  • Anterior posterior modes difficult
  • Lacks full image
  • Visualize several times

Kymograph Accessory!!

HSDI & Kymography

Summary

• New possibilities for aiding decision making of voice disorders

• Information useful for clinic practice as well as basic research

HSDI & Kymography

• Research on vocal physiology
  Vibration is influenced by:
  • Pitch
  • Loudness
  • Phonation Mode
  • Age
  • Gender
  • Disease
  • Improved hardware
    Flexible nasoendoscopy
  • Improved software
    Semi-automated analysis

Thank you

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