Immersive health technologies in cardiology

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Health technologies in cardiology

• Problems facing health providers and patients
• Immersive health technologies
• Clinical validation
• Precision and personalisation
• Benefits of an Island locality
Problems facing modern healthcare

• Costs
• Volume of work
• Provision of 24 hour staffing
• Access to rapid investigations
• Delay (or fear) of implementation of new technologies
## Healthcare costs

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure (£ billions)</th>
<th>Government expenditure (£ billions)</th>
<th>Non-government expenditure (£ billions)</th>
<th>Total expenditure growth rate (%)</th>
<th>Expenditure as % of GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>171.3</td>
<td>136.0</td>
<td>35.2</td>
<td></td>
<td>9.8%</td>
</tr>
<tr>
<td>2014</td>
<td>178.6</td>
<td>142.0</td>
<td>36.6</td>
<td>4.3%</td>
<td>9.7%</td>
</tr>
<tr>
<td>2015</td>
<td>185.0</td>
<td>146.9</td>
<td>38.0</td>
<td>3.5%</td>
<td>9.8%</td>
</tr>
<tr>
<td>2016</td>
<td>191.7</td>
<td>152.2</td>
<td>39.5</td>
<td>3.6%</td>
<td>9.8%</td>
</tr>
</tbody>
</table>

Source: Office for National Statistics (ONS)
EU Healthcare Expenditure Relative To Population Size

Healthcare expenditure per inhabitant in 2015

Luxembourg: €3,557
Sweden: €5,023
Denmark: €4,938
Ireland: €4,273
Netherlands: €4,269
Germany: €4,140
Austria: €4,063
United Kingdom: €3,912
Belgium: €3,812
France: €3,623
Finland: €3,612
Italy: €2,437
Spain: €2,123
Slovenia: €1,596
Portugal: €1,555
Cyprus: €1,408
Greece: €1,361
Czech Republic: €1,157
Estonia: €1,003
Slovakia: €999
Lithuania: €837
Hungary: €806
Croatia: €771
Poland: €718
Latvia: €702
Bulgaria: €518
Romania: €400

Health spending as a proportion of GDP

- Government/compulsory schemes
- Voluntary schemes

UK
- 7.7% Government
- 2% Voluntary

US
- 8.5% Government
- 8.8% Voluntary

*All figures for 2016

Source: OECD
Out-patient attendances

Chart 1: Total outpatient appointments and attendances, 2006-07 to 2016-17

Millions

Source: NHS Digital

<table>
<thead>
<tr>
<th>Main Specialty Code</th>
<th>Main Specialty Code Description</th>
<th>All Attendances</th>
<th>Attended first appointment</th>
<th>Attended first tele consultation</th>
<th>Attended subsequent appointment</th>
<th>Attended subsequent tele consultation</th>
<th>Attended but first / subsequent is unknown</th>
<th>Percentage of all attendances</th>
<th>Follow-up attendances for each first appointment</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Total</td>
<td>93,944,301</td>
<td>28,572,548</td>
<td>968,989</td>
<td>60,694,691</td>
<td>1,177,046</td>
<td>307,427</td>
<td>100.0%</td>
<td>2.5</td>
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<tr>
<td>320</td>
<td>Cardiology</td>
<td>2,913,121</td>
<td>1,177,383</td>
<td>9,591</td>
<td>1,004,032</td>
<td>57,370</td>
<td>4,725</td>
<td>3.1%</td>
<td>1.5</td>
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</table>
Immersive technologies

The application of devices that blur the line between the physical world and digital or simulated world, thereby creating a sense of immersion.

**Virtual Reality (VR)** is a completely immersive experience in which users are taken from their real-world surroundings and placed virtually into an entirely new digital environment.

“I know it’s not real but it feels real”

**Augmented Reality (AR)** users can still see the environment around them, but digital content is overlaid into their space.
Business opportunities

The Diverse Potential of VR & AR Applications
Predicted market size of VR/AR software for different use cases in 2025*

- Total $35.1b
- Consumer $18.9b
- Enterprise and public sector $16.1b

- Healthcare $5.1b
- Engineering $4.7b
- Real estate $2.6b
- Retail $1.6b
- Military $1.4b
- Education $1.3b
- Videogames $0.7b
- Live events $0.4b
- Video entertainment $3.2b

* Base case scenario
Source: Goldman Sachs Global Investment Research

Healthtech market expected to grow materially

Source: Statista, Credit Suisse
Virtual Reality (VR)

Virtual Reality is a completely immersive experience in which users are taken from their real-world surroundings and placed virtually into an entirely new digital environment.

- Early use in games and simulation training
- Pain control / PTSD / phobias
- Resilience / motivational training
- Engagement / teaching
Virtual reality in cardiology

Physiological response
- Using VR environments to assess physiological response to visual stimulus
- Assess heart rate variability, response to medication, virtual stress test

Pain control
- Visual stimulus reduces need for pain relief or sedation
- Pacemaker implants

Psychotherapeutics
- PTSD
- Anxiety / depression
- Cardiac rehabilitation
- Heart rate control for procedures (CTCA)
Stanford Virtual Heart Project

Education

Lucile Packard Children's Hospital, Stanford VR technology to explain complex congenital heart defects
Cardiac rehabilitation

Exercise with VR component
Improved exercise duration
Reduced sympathetic tone
Greater recovery following intervention
Sim training / CPD

Training

VR environments to assess trainees response to scenarios

Possibility to include physiological measurements

CPD?
Augmented Reality (AR)

Augmented Reality users can still see the environment around them, but digital content is overlaid into their space

- Teaching / training
- Medical simulation
- Virtual consultations
- Emergency care - avatars
Holoanatomy

Cleveland Clinic
Microsoft HoloLens

“Will allow medical students to perform holographic dissections”
Echopixel

Enables a user wearing AR glasses to visualize and manipulate cardiovascular anatomy from standard databases.
AR simulation and consults
Access to new technologies

CTCA
CT coronary angiography accepted as standard care for patients with suspected coronary heart disease
Access limited and projected increase X3+ in UK

Staff and reporting
Limited numbers of cardiologists/radiologists
CT time pressures
Remote reporting / AI

**Caristo**

Perivascular inflammation using Fat Attenuation Index (FAI)

Strong predictor of cardiovascular risk

Replacement for calcium score and other risk markers?

**Heartflow**

Non-invasive assessment of fractional flow reserve

Guiding coronary intervention

Independence from costly trained staff?

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1-Year Outcomes of FFR_{Cor} Guided Care in Patients With Suspected Coronary Disease: The PLATINUM Study


1-Year Outcomes of FFR_{Cor} Guided Care in Patients With Suspected Coronary Disease

Journal of the American College of Cardiology

Volume 60, Issue 5, August 2012

DOI: 10.1016/j.jacc.2012.5.007
Wearables and data connectivity

Wearables

Vast increase in connected devices
IOT
5G networks

What to do with the data?

**Wearables**

**While sleeping**
Advances in electrodes small and flexible enough to fit in textiles could lead to pillow-cases and sheets able to monitor brain waves and sleep patterns.

**Upon waking**
Toilets that check urine and stool for disease are being developed. In the future, smart mirrors could measure vital signs with radar, and toothbrushes might analyze saliva.

**In the kitchen**
Smart refrigerators might soon monitor the food stored and record its nutritional information. Food quality and freshness would be tracked, along with dietary habits.

**Plugged in**
Smartphones could analyze patterns that might indicate depression—such as a drop-off in social communication—and alert the user to address potential mental health issues.

**In the car**
Sensors could warn a driver about dangerous pollution levels, high blood alcohol content detected on the breath, and driving that indicates stress and drowsiness.

**On the run**
Electronics like Fitbits or electric membranes attached to the skin can track exercise, vital signs, and ultraviolet exposure, while a "smart bra" might detect breast cancer.

**In your body**
Contact lenses may soon check pressure and glucose levels in the eye. Implantable technologies already monitor cardiac activity, nitrogen, and oxygen levels.

**In the lab**
"Electronic noses" could detect volatile organic compounds in the breath or in secretions such as sweat and saliva to find "smellprints" of diseases, including lung and ovarian cancer.
The data are interesting
But do they provide value?
Does monitoring make someone feel better or live longer?
Does monitoring reduce health care costs or increase them?
Where to access data?

A positive feedback loop
An individual’s health risk factors are assessed, then compared with large-scale population data, which can suggest beneficial choices or interventions. Passive monitoring throughout the day is key to constantly improving outcomes.

- Family history
- Genetic screening
- Socioeconomic factors
- Environmental factors

- Machine learning
- Pattern recognition
- Early medical intervention
- Behavioral changes

JASON TREAT, NGM STAFF; KELSEY NOWAKOWSKI
ART: CHRISTOPHER DELorenzo
SOURCE: SANJIV SAM GAMBIHR, STANFORD UNIVERSITY
Patient centred records

Silo mentality of multiple health data repositories. Focus needs to switch away from the institution / company to the patient

- Patient as the data controller
- Portability and connectivity
- Access to new applications / providers
- Potential for device / software integration and testing
Testing and validation

Rapid access to quality-assured, outcome measured clinical research. But how and where?

<table>
<thead>
<tr>
<th>Where</th>
<th>Providing</th>
<th>Perhaps</th>
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</thead>
<tbody>
<tr>
<td>Smaller communities</td>
<td>Public and professional motivation</td>
<td>The Island as a platform?</td>
</tr>
<tr>
<td>Less geographically mobile</td>
<td>Enabling healthier populations</td>
<td></td>
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<tr>
<td>Collaboration between</td>
<td>Law review and change</td>
<td></td>
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<tr>
<td>primary and secondary care</td>
<td>Stimulating new economies</td>
<td></td>
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<tr>
<td>Smaller number of health</td>
<td>‘Walled garden’ or ‘Shored garden’</td>
<td></td>
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<tr>
<td>record systems</td>
<td></td>
<td></td>
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<td>Independent health</td>
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<td>regulators</td>
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</table>
Local government initiative to promote Jersey as a leading digital health testing and innovation locality

Size - 118.2 sq. km (Area)
GDP - £4.11 billion
Population - 102,700
Airport - 1.5+ Million People
30+ Destinations
World-Class Finance Industry
- 13,000 Financial Professionals

Investment in Fibre Connectivity, 4G
Digitally enabled population
Active Tech Community
Stable, Independent & Responsive Government

Strong Public Finances & a Competitive Tax Base
World-Class Data Centres & Extensive Telecoms Network
Privacy for R&D

#sandboxjersey
The efficacy of a smartphone ECG application for cardiac screening in an unselected island population

Pierre Le Page, Hamish MacLachlan, Lisa Anderson, Lee-Ann Penn, Angela Moss, Andrew R J Mitchell; from the Jersey International Centre for Advanced Studies

Cardiac screening in the community is limited by time, resources and cost. We evaluated the efficacy of a novel smartphone application to provide a rapid electrocardiogram (ECG) screening method on the Island of Jersey, population 98,000.

Members of the general public were invited to attend a free heart screening event, held over three days, in the foyer of Jersey General Hospital. Participants filled out dedicated questionnaires, had their blood pressure checked and an ECG recorded using the AliveCor (CA, USA) device attached to an Apple (CA, USA) iPhone 4 or 5.

There were 989 participants aged 12–99 years evaluated: 954 were screened with the ECG application. There were 54 (5.6%) people noted to have a potential abnormality, including suspected conduction defects, increased voltages or a rhythm abnormality requiring further evaluation with a 12-lead ECG. Of these, 23 (43%) were abnormal with two confirming atrial fibrillation and two showing atrial flutter. Other abnormalities detected included atrial and ventricular...

Introduction

Atrial arrhythmias are often asymptomatic and can remain undiagnosed until presentation with stroke or heart failure. Pulse checks can help detect atrial fibrillation (AF) but a recorded electrocardiogram (ECG) remains the gold standard.¹

We set out to identify the effectiveness of a hand-held, single-lead ECG device to identify arrhythmia and other ECG abnormalities in a large, asymptomatic, unselected island population.
Population screening
DNA database
Linked to Jersey Care Record
Conclusions

The rapid evolution of digital health technologies has created one of the most exciting times in history to be in the field of medicine

- Immersive health technologies - VR / AR
- Patient centred records
- Patient-driven data generation and genomic revolution
- Personalised, precision based medicine