Competitor analysis of wearable oximeters suitable for home monitoring

For

Viamed Ltd

(Part of the SBRI Healthcare Project)

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TRANSFORMING HEALTHCARE

Contents

1. Executive summary

The SBRI funded project around home monitoring of oxygen saturation in paediatric patients identified that current solutions are project originated from unmet needs defined by the Technology and Innovation Transforming Child Health (TITCH) network that identified that current technologies and products on the market are unsuitable for monitoring children particularly in the home environment.

An assessment was made of both products on the market and patent filings of companies that are currently active in the oximeter market.

There are over 1200 patent families that mention the work 'oximeter' in the title. This does not include filings that use other descriptive phases). Due to the large number of filings in the oximeter field it was impossible to review every patent. A deeper assessment of Masimo was conducted than the other companies, but key trends and examples of key patents from other players was also covered.

- *Masimo (see section 3.1)*
    - Masimo are moving in the direction of remote monitoring, wireless technologies, and transfer of data and integration of data into patient records. Masimo have little IP in the area of 'digital connectivity' and although this need monitoring (it is possible some has not yet been published). From a top level IP perspective Masimo have traditionally filed patents in the US, but not in Europe (although there are some exceptions). Many of the early Masimo patents have also now expired. This means that although the IP opportunity needs monitored in relation to individual Masimo patents the early analysis indicates that freedom to operate should not be a problem (for many concepts), but that the potential to create new IP needs to be considered on a concept to concept basis.
- *GE Healthcare (see section 3.2)*
    - GE Healthcare market standard oximetry products and do not appear to be innovating in the oximetry field at the present time. There is currently no evidence they are moving towards wearables or remote monitoring
- *Phillips Respironics (see section 3.3)*
    - Philips are active in the areas of oximetry and their market products show a trend towards wearables and remote monitoring. From an R&D perspective they have several recent patent filings in the sensor area including a sensor that monitors infants via a facial tissue. The progress and patent status of intellectual property held by Philips should be monitored during the duration of the project.

      In addition, other Philips devices that they have in the sleep market include sleep quality and movement detection functions. Customer need analysis should determine whether any additional functionality would add value to the device.
- *Biochem International/ BCI (see section 3.4)*
    - There has been a historical focus on single use oximeter devices. However there has been no recent patent activity suggesting the company is not currently focussing developing new products in this area.

- *Nonin Medical (see section 3.5)*
    - Noni have had a clear strategy of developing wireless devices over the last few years and this is reflected in the launch of the Onyx® II 9560 wireless oximeter (Nonin Medical claim to have marketed the world's first wireless finger oximeter) and the filing of several patents in this area. It is unclear at this time whether any of these patents will be granted as initial submissions have been appear to have been rejected. The legal status of these patents needs monitoring during the duration of the project. Significantly the company have focussed on intellectual property protection in the US and as such even if granted these patents might not affect the freedom to operate in Europe (a patent attorney would be required to validate this assumption).

- *Covidien / Medtronic summary (section 3.6)*
    - Medtronic have filed 336 patents in the area and as such the search was limited to key patents and trends from 2010 to the present day. Recent patent filings cover areas such as performance in moving patents, wireless monitoring, alarms, calibration and low power devices and these should be monitored for legal status and new filings during the duration of the project.
- Konico Minolta (section 3.7)
    - There have been 21 patent filings identified by Konica Minolta the most recent ones focus on wearable finger probes, which is reflected in recent product launches such as the Pulsox 300 with wearable probe. The patent activity of Konica Minolta should be monitored and their patent filings should be reviewed prior to future patent filings.
- Technical search (section 4)
    - A broader technical search was conducted to identify technical trends and this shows there are additional companies that Viamed should be aware about that are developing potential disruptive technologies. For example, Everyone Care Technologies is developing oximeter based technologies to detect early sepsis and is developing probes for non-traditional based parts of the anatomy such as the upper shoulder or chest. A second UK based company Intelesens that focusses on intelligent, wireless, vital signs monitoring and screening technologies has a granted European patent and is currently challenging the US patent office regarding a patent describing a chest based wireless sensor that utilises a hydrogel contact layer. Although a detailed assessment of clinical review of clinical data was not part of this review, some data was identified showing oxygen saturation readings from sensors in the chest and finger correlated, but that the chest site detected falls in SpO2 more rapidly therefore allowing the clinicians to implement a treatment more rapidly.

In summary, the data shows there is a clear drive to wireless devices and remote monitoring and that while there is activity around calibration and noise reduction the design, placement and design of sensors might offer an avenue to reduce artefacts while generating strong IP (although the device might have to incorporate Bluetooth or wireless functionality to meet future needs.

In general terms many of the key players have intellectual property that covers the US and not Europe (although there are exceptions). This means that for a European market freedom to operate might not be a large barrier (but individual inventions will need to be assessed), although this does not necessary equate to an invention being patentable as the team will need to demonstrate that any new patentable invention is novel, non-obvious and reduced to practice. Although there are patent filings on wireless solutions companies appear to be having these rejected or challenged (some are on ongoing correspondence). There are a small number of granted patents (in the US rather than Europe) and more detailed assessment of these should be made as the project progresses.

This report is intended to be a top level broad report and is intended to help with product positioning and idea generation and defining the overall intellectual property strategy. As the project progresses into phase II a much more detailed searches will need to be conducted based on the specifics of the concepts created during phase I by the project team.

2. Background

Many diseases of children such as chronic lung disease, cystic fibrosis, asthma and bronchiolitis are related to the child's ability to oxygenate their blood. Current monitoring solutions have limitations in their design that limit performance resulting a risk of morbidity and death leading to pressures in A&E departments. There are estimated to be 24,000 emergency admissions related to children with breath difficulties. These take up approximately 80,000 bed days.

This project originated from unmet needs defined by the Technology and Innovation Transforming Child Health (TITCH) network that identified that current technologies and products on the market are unsuitable for monitoring children particularly in the home environment.

Currently available technologies are largely adult solutions that have been adapted for use in children, infants or neonates. These technologies are cumbersome, lack Paediatric algorithms, motion creates artefacts, toe and finger probes limit movement and the devices on the market generally exhibit low perfusion performance.

Current devices that have been on the market for a number of years largely fall into four categories (see figure 1).

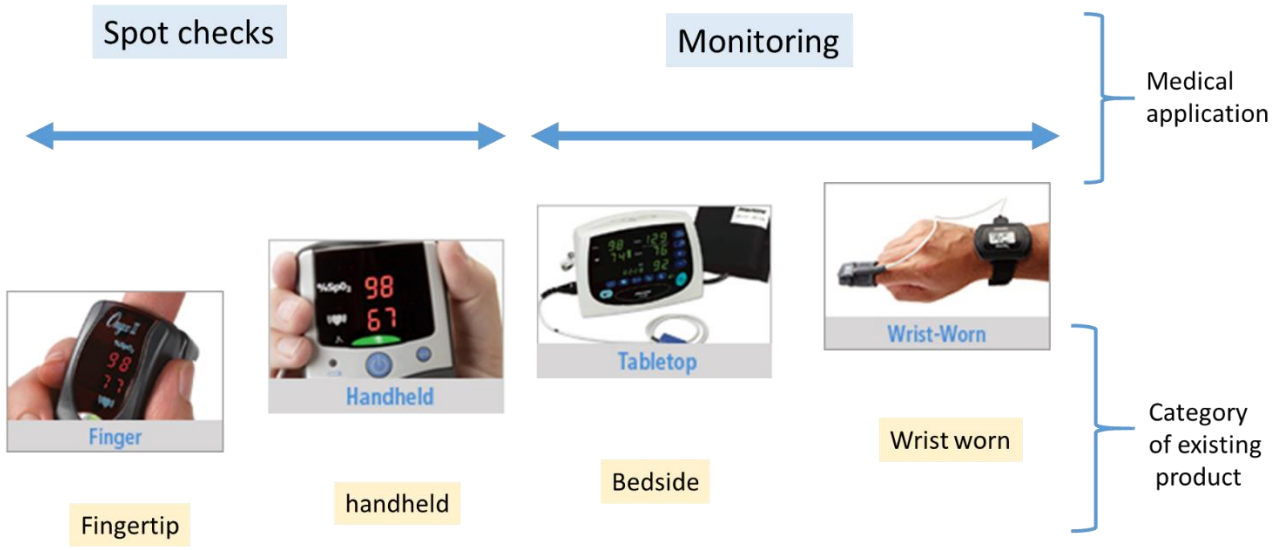


Figure 1: A summary of current types of oximeter on the market. The examples are from Nonin and it is common for companies to have products in each category. Ethnography conducted by the Medilink team at Sheffield Children's Hospital identified patient using devices intended for spot checks for long term monitoring. The segmentation shown above is therefore simplistic as patients and their families appear to be using devices in a manner not intended by the manufacturer(s).

Types of oximeter

I. Fingertip. A pulse oximeter with an integrated fingertip probe that incorporates a visual display and records results.
II. Handheld. A pulse oximeter that displays and record result and is intended to be used in the hand during normal use. Probes are connected to the handheld unit via a cable.
III. Bedside/desktop. A pulse oximeter that sits on a desk or stand. Probes or sensors are connected to the unit via a cable or wireless link.
IV. Wrist-worn. A pulse oximeter that is worn on the wrist during normal use. Probes are connected via a cable and the sensor is normal attached to a finger.
V. There are also nose and head oximeter sensors that are also in clinical use.

As shown in figure 1 the hand held and fingertip units tend to be used for spot checking. Monitoring usually uses bedside type units although the wrist type devices are increasing being marked by companies with the benefit that they can be used by a mobile patient (including in their home environment).

This competitor analysis is not intended to review every single oximeter in the market, but to identify those related to remote monitoring, to identify the strategic direction of competitors and to identify the space to operate with respect to freedom to operate and the creation of new intellectual property.

In the sections below section 3 assesses offerings of key competitors and is broken down to overview of products on the market and appraisal of patent filings. Each company's appraisal contains a summary section detailing the strategic direction of the company together key intellectual property the development team should be aware about.

Section 4 addresses the competitive landscape from a technical perspective rather than from that of the competitors. In this section technological search terms are used rather that names of companies. Using these two approaches reduces the risk the relevant patents will be omitted.

This report is intended to be a top level broad report and is intended to help with product positioning and idea generation and defining the overall intellectual property strategy. As the project progresses into phase II a much more detailed searches will need to be conducted based on the specifics of the concepts created during phase I by the project team.

3. Competitor descriptions

3.1. Massimo Corporation

3.1.1. Masimo oximeters

Massimo were the first company assessed as they are a large corporation and put considerable effort into R&D pipeline. Their overall focus is non-invasive patient monitoring technologies and pulse oximetry devices represent a large proportion of their business.

Figure 2 shows the product launches of Masimo since 1996 when their first pulse oximeter with the Signal Extraction Technology (SET) technology was developed. The Rainbow Pulse oximetry system was launched in 2005 and is a platform that measures other blood constituents such as total hemoglobin (SpHb™), oxygen content (SpOC™), carboxyhemoglobin (SpCO®), methemoglobin (SpMet®) and pleth variability index (PVI®). Some models (e.g. Rad-97) are sold as basic oximeters, but are upgradable to incorporate the Rainbow technology. Alternatively higher spec models can be purchased with the Rainbow technology.

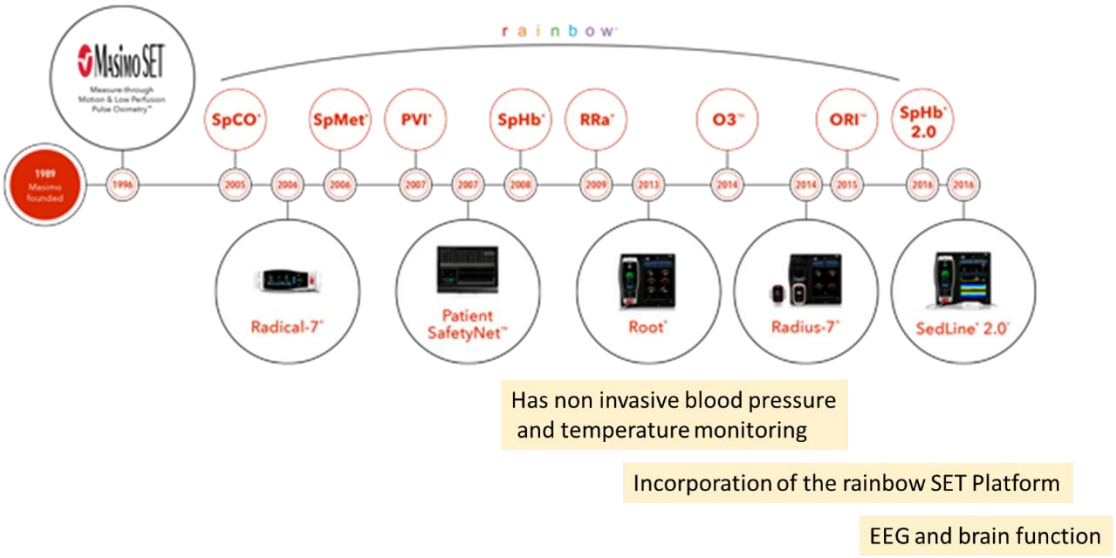


Figure 2: Masimo Pulse oximetry product launches (adapted from http://www.masimo.co.uk/aboutmasimo/evolution.htm)

The SET platform is claimed by Masimo as the world's first oximetry technology that could measure through motion and low perfusion (see http://www.masimo.co.uk/whymasimo/difference.htm).

The claimed theory and proposed advantage of the Masimo SET technology is that conventional pulse oximetry assumes it is measuring arterial blood, but during movement venous blood also moves, which causes conventional oximetry to under read because it cannot differentiate between venous and arterial blood. The proposed advantages to clinicians involved detecting life threatening events whilst minimising false alarms.

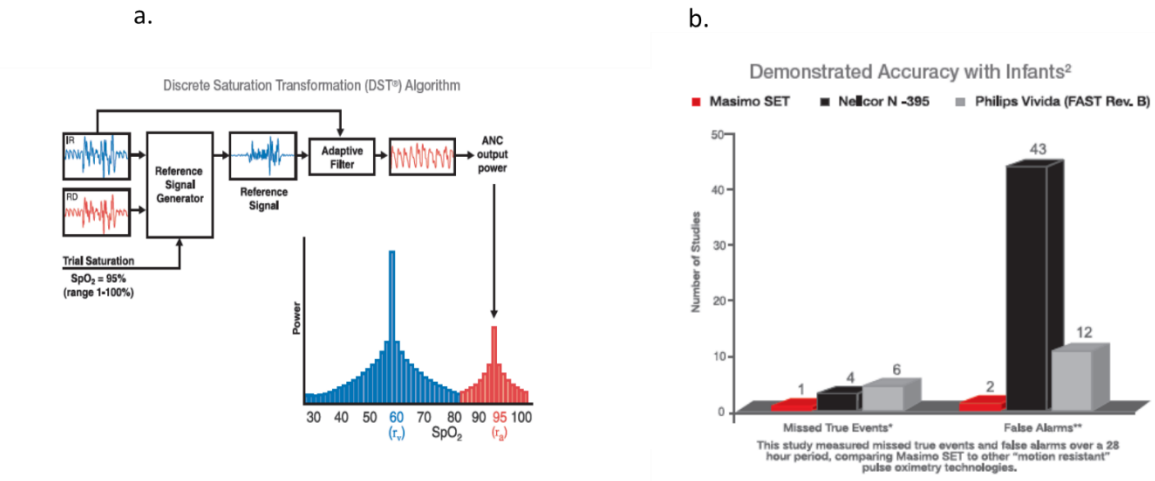


Figure 3: a) Summary of the SET technology. b) Clinical evidence.

The SET technology is based on the use of adaptive filter applied to real-time physiologic monitoring. Masimo claim that they use patented algorithms that work in parallel to establish an accurate noise reduction level to ensure continuous, accurate SpO2 measurement, even under the most challenging conditions (i.e. movement or low perfusion). The focus of this report is not to evaluate clinical evidence. However, Masimo claim to have over 100 independent publications that support there technology and many of these differentiate their product in terms of performance from competitor offerings. The clinical data is potentially relevant to Viamed as if equivalence can be shown in comparative benchmarking tests an argument could be created for equivalence thereby allowing Viamed to use Masimo clinical data to support the benefits and safety of the Viamed devices (e.g. in MED DEV 2.7.1 Rev 4 Clinical Evaluation reports).

The focus of this assessment is not to review all existing products as companies such as Masimo market products in the categories shown in figure 1. However with regard to technical trends and strategic direction it is important to note that some Masimo devices now have wireless connection and via Bluetooth™ of Wi-Fi connectivity can translate data directly to smart mobile phones or other devices. Figures 4 and 5 show two existing solutions. Figure 4 shows a finger sensor (with integrated board) and Blue tooth transfer of data to a mobile phone.

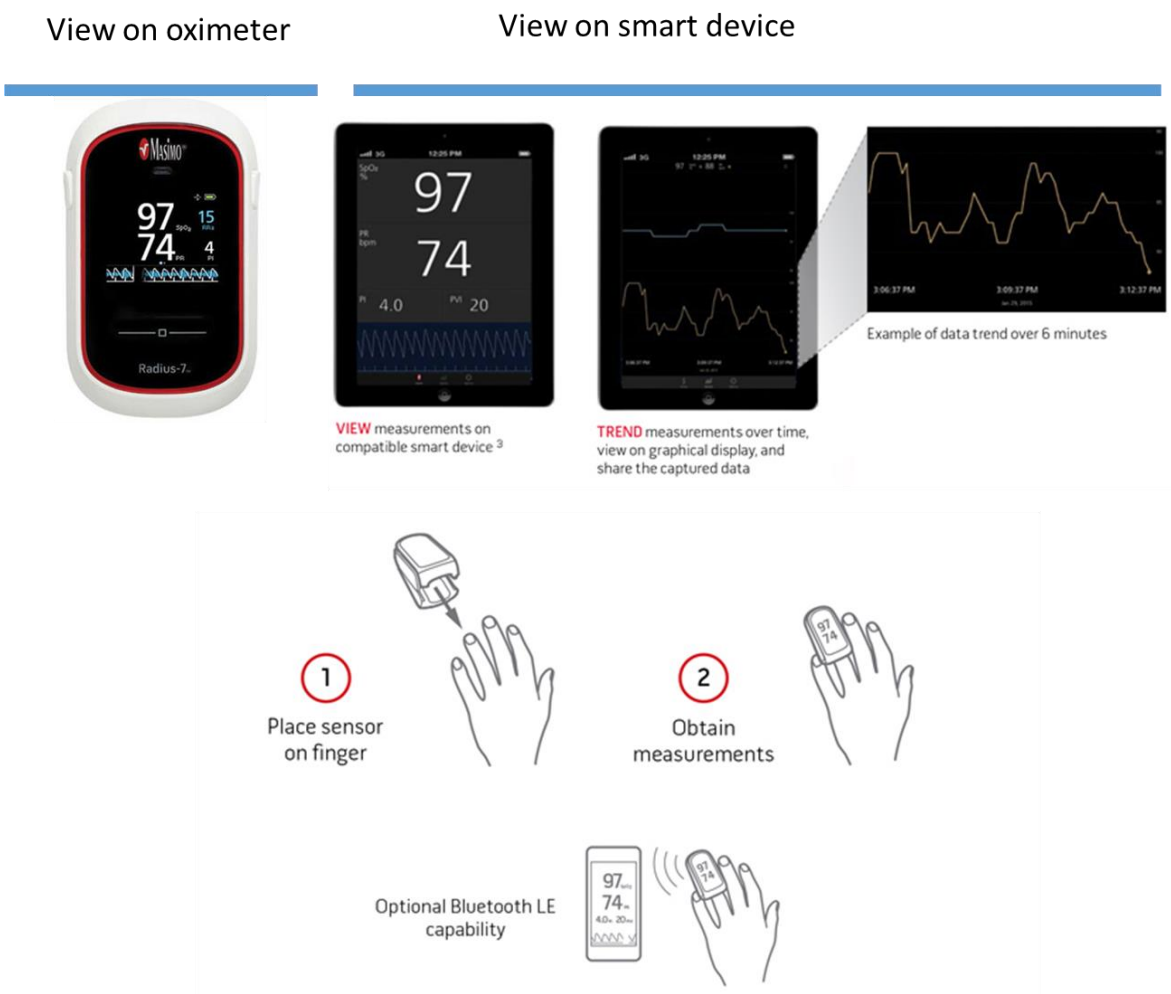


Figure 4: The transfer of oximetry data to mobile phone and data being visible on a freely available app. Adapted from the Masimo website.

The fingertip oximeter (MightySat™ RX Fingertip Pulse oximeter), which is represented in figure 4 comes with a free downloadable app that can be viewed on a compatible smart device (http://www.masimo.co.uk/pulseOximeter/mightysatRx.htm). These apps typically can measure trends and can share the captured data. The data from the sensor can be transferred to the smart device via blue tooth. The free downloadable Masimo Professional Health App, marketed on the Masimo UK website, shows identical data that is presented on the oximeter itself. Importantly this also records the pleth waveform.

Figure 5 shows an alternative solution in which the board is integrated into a cable that connects to a small sensor. The cable then connects directly to the smart phone that can visualise and record data.

Figure 5: The board in cable solution. The board is located in a cable that can be connect at one end to the sensor and at the other end directly to a mobile phone.

3.1.2. Masimo Sensors

Masimo have a range of sensors that Masimo claim are differentiated in terms of patient comfort (see figure 6 and http://www.masimo.co.uk/sensors/RD%20SET%20Sensors.htm). These are thin low profile sensors that allow the sensor to conform to the shape of the finger. The fold over sensors are differentiated in that they claim more secure application and intuitive sensor alignment (see figure 6c). The wrap round type sensors claim to be easy to apply and remove and are also suitable for patients with long fingernails or finger deformities. However despite claims from companies such as Masimo that their sensors are differentiated interviews with clinicians at Sheffield Children's Hospital conducted by Medilink on the 25th January 2017

Figure 6: Examples of Masimo sensors.

Typically Masimo systems claim an accuracy of 2% for paediatric and 3% for neonates (for movement and non-movement).

Finally the company market the green credentials of their lightweight RD SET cables due to them producing less waste than a conventional cable (see http://www.masimo.co.uk/sensors/RD%20SET%20Sensors.htm).

3.1.3. Exchange of data from remote patients

In the sections above the data shows that there is a trend to gather data on a mobile phone via miniaturisation and that this data can be viewed by the user or clinicians if present. Masimo have also developed systems to relay this data to clinicians remotely and provide data, notifications or alerts.

The Masimo solution Patient SafetyNet appears a be a means that the clinicians can then remotely monitor patients by plugging the system into an existing wired or wireless network (see figure 7a). This is essentially a patient monitoring and clinical notification system and connects patients to caregivers by giving near real time information from any connected Masimo device at a central station and allows alarms and alerts to be sent to clinicians via pager or smart phones. In addition in March 2016 Masimo launched its Iris™ Gateway which is a server based software solution that integrates medical device data and can translate the data from devices into patients' electronic medical records (EMRs). It is significant that the Iris™ Gateway can be used with third party stand-alone devices (see figure 7b)

a. b.

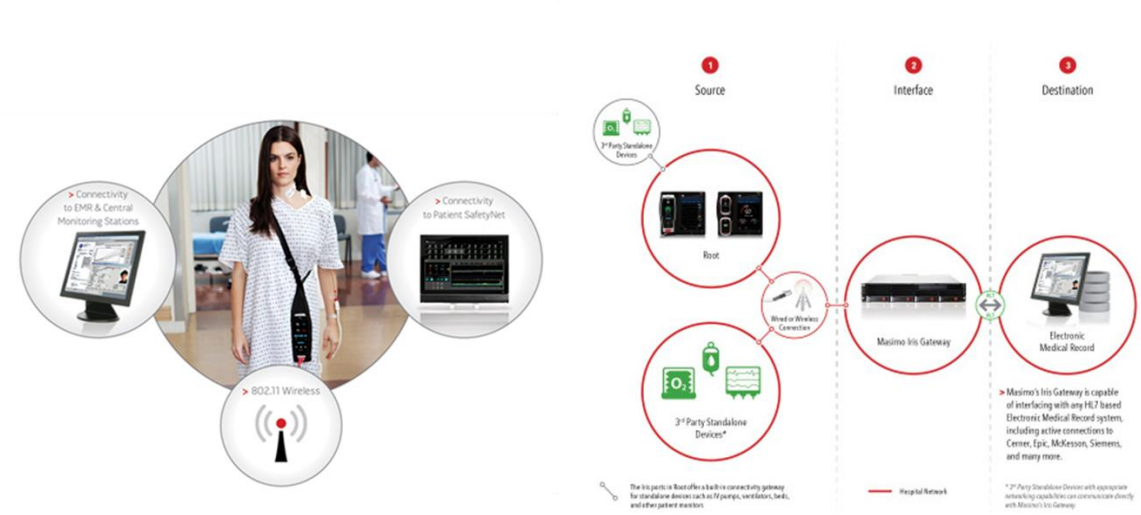


Figure 7: a) The Masimo Patient SafetyNet solution that allows remote oximeter reading and b) the Iris™ Gateway that allows integration of monitoring data from Medical devices into the patient's electronic patient record.

3.1.4. Map of Masimo patents

When Masimo was entered in the worldwide Espacenet search engine 905 patents were identified showing that the company has a very strong emphasis on securing new intellectual property as a driver of growth.

Within the scope of the project it was impossible to assess all patents or to do an assessment of the overall direction of Masimo. A separate search was therefore conducted that looked at the terms "oxygen" in the title or abstract and "Masimo" as the applicant. 47 patents were arranged into listings based on priority dates identified 30 patent families. These were assessed. An overview of patents filed since 1998 is shown in figure 8. There are other patents filed pre-1997, but these are now off patent and although should be considered during future patenting these pre -1997 patents are irrelevant with respect to freedom to operate.

Pre 1997 patents include low noise optical probes, finger cot probes and a variety of patents related to calculations of physiological parameter. A further search looking at "oximeter" and "Masimo" identified 107 patents that when prioritised in terms of priority dates resulted in 41 patents.

A summary of patents filings is provided in figure 8 which shows 1999-2002 was the most prolific phase of patent filing with patents aspects such as multiple wavelengths, alarm systems, and software linked to signals. There is one patent US6850788B2 that describes a wireless link created by a plug adapter. This however it is based on outdated technology and it is likely this would not impact similar

solutions. Critically this patent as with the majority of Masimo's patents do not cover Europe or the Middle East (most but not all of Masimo's patents are restricted to the US).

Since 2003 Masimo patent filings have been much more restricted and focused. Notably these cover multiple blood components (US858173B2), which is the IP that protects their Rainbow™ platform. More recent patents included US9131881 "Hypersaturation index" that provides an indication of the partial pressure of oxygen of a patient. This appears to be based on a hypersaturation index that is calculated based on the absorption ratio of two different wavelengths of energy at a measuring site. The two most recent published patents, neither of which are yet granted, describe the user display and interface. As an example of the type of elements this covers the patent description states that "One view presents a first trend graph of the first physiological signal and a second trend graph of the second physiological signal". Masimo have filed this patent in Europe and other regions (e.g. Japan), which suggests Masimo might have changed their strategy and are now seeking wider global protection for new innovations.

One patent application relates to finger pulse oximetry sensors configurations including removable sensor sleeves, removable sensor pads, and light blocking configurations (US2013096405). The most recent patent that Masimo have filed describes an advanced pulse oximeter sensor that discloses a means to reduce errors by a sensor that has an emitter and a diffuser to receive and spread the emitted light. The system further includes a concentrator configured to receive the spread light after it has been reflected from the tissue measurement site (US2017000394). This indicates that Masimo are trying to develop sensor design to minimise errors and that the status of their IP should be monitored.

At this stage a detailed assessment and review of the legal status of every Masimo patent could not be conducted. However as the project moves forward a more focussed IP assessment focussing on the designs or potential designs of the Viamed solution should be conducted. Due to the high number of Masimo patents a more detailed and focussed assessment of IP that might be relevant to the new oximeter needs to be conducted following prioritisation of concepts and as priority during phase 2 of the project.

In addition, every variation in search term such as probes, sensor and others could not be used within the scope of this initial patent assessment that is intended to determine the broad patent landscape. It is therefore possible that some key patents might not have been identified in this broad assessment.

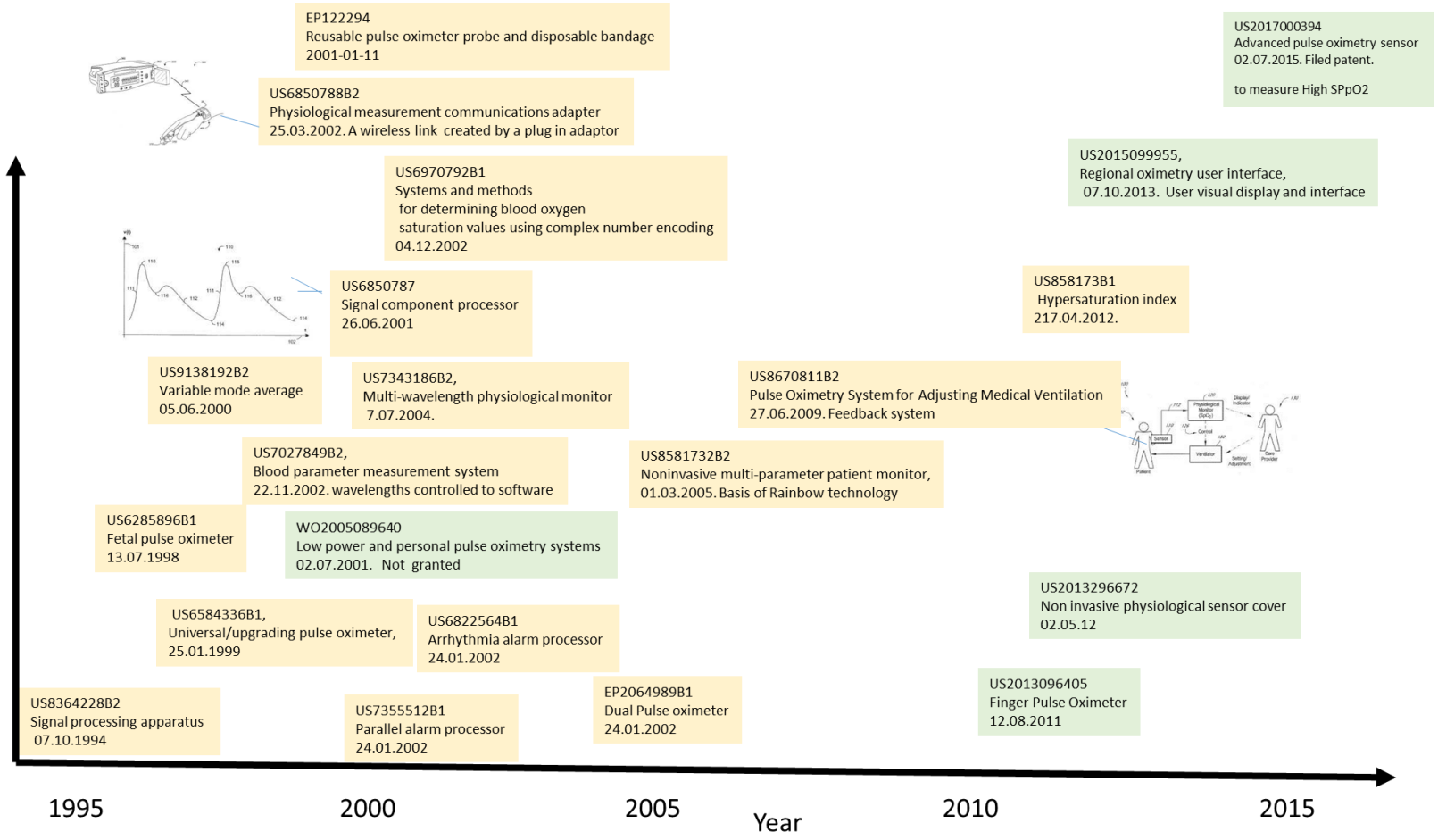


Figure 8: Patent map of key patents filed from 1998. Yellow boxes represent granted patents (although mainly in the US) and green boxes represent filings (which might be granted or patent pending).

A top level assessment of Masimo patents show.

- The majority of patents are filed only in the US (there are one or two exceptions). This means as a company Masimo have relatively weak patent protection in Europe showing that Viamed should have a gap for European markets (provided that patent has not been filed in the EU). Once concept(s) are defined more focused assessments of appropriate patents should be conducted together the legal status of relevant IP.
- There is almost no IP relating to wireless transfer of data (other than US6850788B2), which is a specific solution and should be relatively easy to circumnavigate.
- The assessment only looks at published patents. Normally it takes 18 months from the date of filing to publication. Hence the search could identify patents filed after June 2015.

3.1.5. Summary of Masimo trends

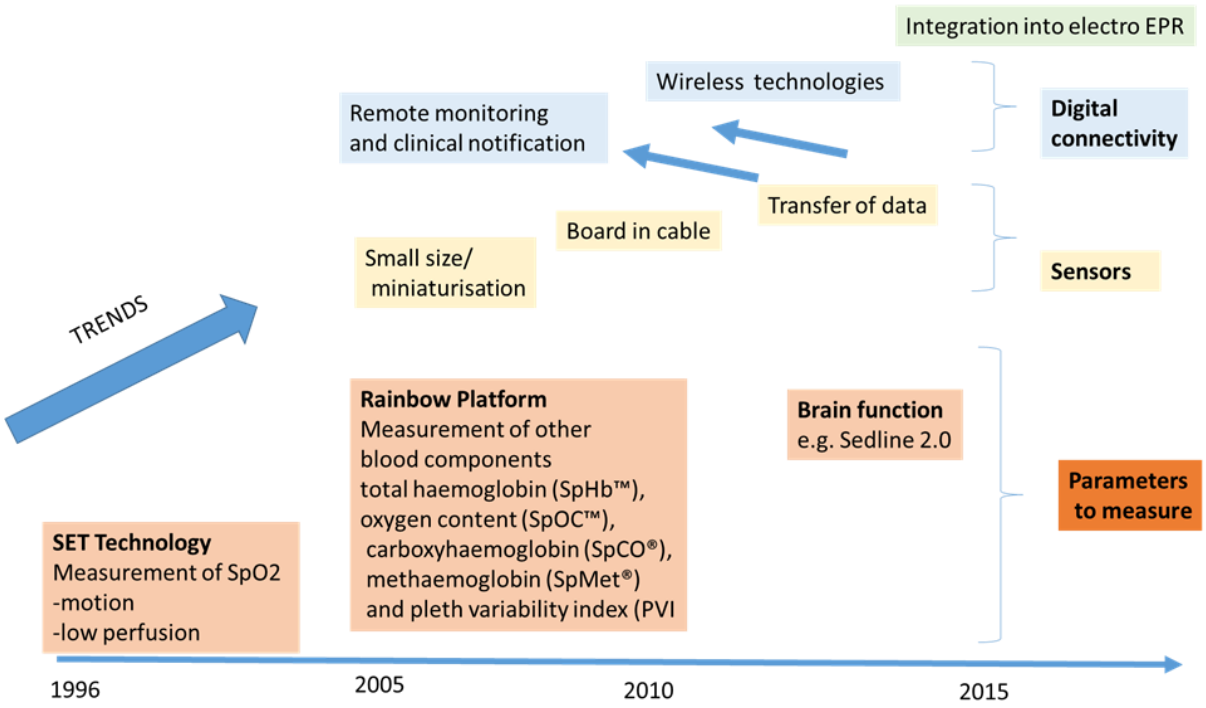


Figure 9: Summary of Masimo trends

Masimo Summary

Masimo are moving in the direction of wireless technologies, transfer of data and integration of data into patient records. Masimo have little IP in the area of 'digital connectivity' and although this need monitoring (it is possible some has not yet been published). From a top level IP perspective Masimo have traditionally filed patents in the US, but not in Europe (although there are some exceptions). Many of the early Masimo patents have also now expired. This means that although the IP opportunity needs monitored in relation to individual Masimo patents the early analysis indicates that freedom to operate should not be a problem (for many concepts), but that the potential to create new IP needs to be considered on a concept to concept basis.

Masimo are moving in the direction of remote monitoring and their activity in this area should be monitored.

Masimo are considered the leaders in the oximetry field and as such emphasis has been put on understanding the strategy of the company, their technological trends and their IP landscape. Due to the constraints to the project a detailed assessment could not be conducted for every company in such detail. However an overview and summary of intellectual property related to oximetry is provide in sections 3.2

3.2. GE Healthcare

GE Healthcare market the TuffSat® Handheld Pulse oximeter with a range of reusable and disposable probes (see figure 10). The device can fit into a pocket or can be worn on belt and the company attempt to differentiate in terms of a relative perfusion index measurement, which enables (according to the company) easy identification of the signal quality and can help find the best site for the sensor. The device is intended for spot checking.

The company also market a desk top device, the GE Ohmeda Trust device, which is also marketed as being 'portable' and suitable for use in the home environment (see figure 10d)

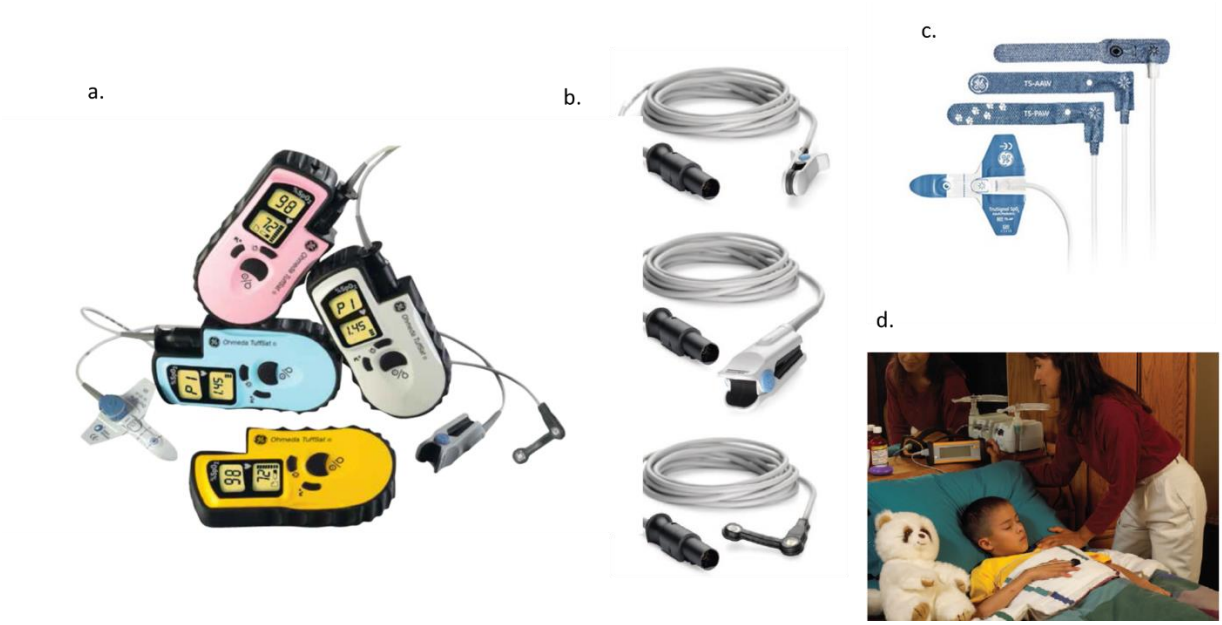


Figure 10: a) the TuffSat Hand held Oximeter, b) reusable sensors and c) disposable sensors and d) the GE Ohmeda Trust device.

A patent search was conducted using “oxygen” and “GE Healthcare“ as assignee. This search revealed 17 hits, none of these related to oximetry related applications. A separate search of “GE” as assignee and “oximetry” identified four relevant patents, all of which were filed and maintained only in the US. Significantly the patent map shows that in the early and mid-2000’s GE Healthcare were actively conducting R&D in the oximetry field (see figure 11). The lack of filings over the last decade suggests the GE Healthcare are no longer actively conducting R&D effort in the area of oximetry.

The granted patents shown in figure 11 have been maintained showing that whilst GE Healthcare do not appear to be conducting current R&D in the area they are maintaining their IP in the US to support current products.

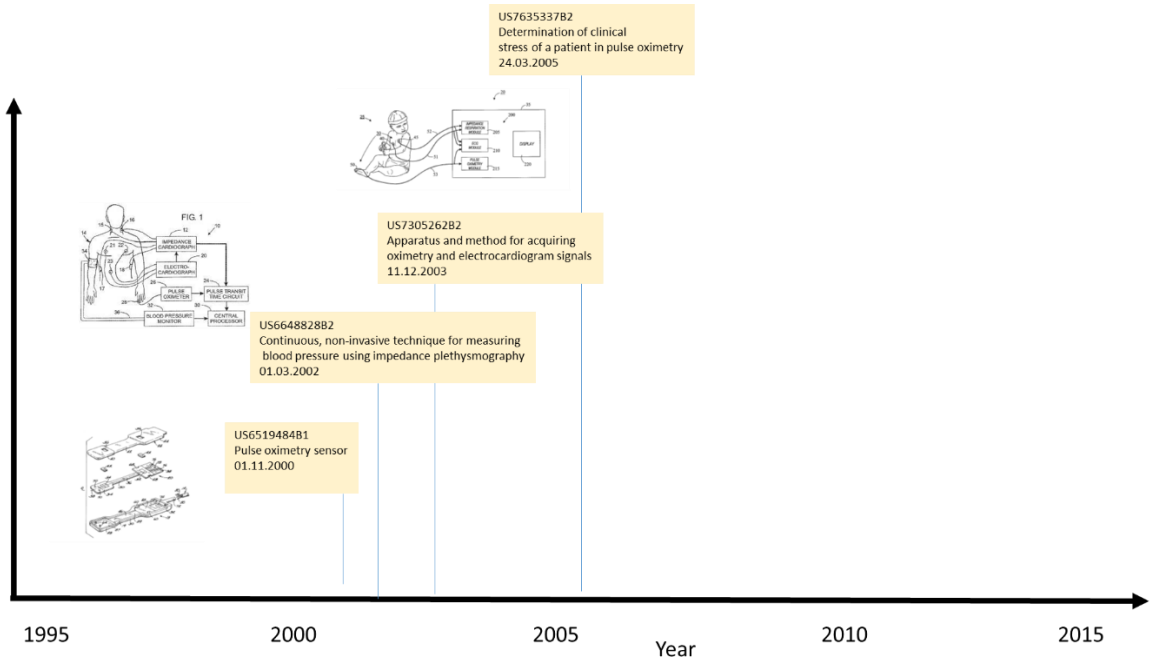


Figure 11: Oximetry related patents filed by GE Healthcare

GE HealthCare Summary

GE Healthcare are marketing standard products and do not appear to be innovating in the oximetry field at the present time. There is currently no evidence they are moving towards wearables or remote monitoring

3.3. Philips Respironics

Philips Respironics specialises in the sleep and respiratory markets. The company have a wide product portfolio including products for sleep apnoea, COPD and home oxygen systems. They also market oxygen airway clearance devices, nebulisers and a range of devices that monitor the quality of sleep (http://www.philips.co.uk/healthcare/solutions/sleep-and-respiratory-care/oxygen).

Philips do have an active strategy to move into the wearable biosensor market and should be considered along with Masimo a key competitor to benchmark future devices. The vital signs that the Philips medical device type biosensors will measure include heart rate, respiratory rate, and skin temperature. The main driver and unmet need that Philips are addressing are to detect early signs of patient deterioration and intervene early (see http://www.philips.co.uk/a-w/about/news/archive/standard/news/press/2016/20160222-Philips-to-introduce-next-generation-monitoring-solution-enabled-by-wearable-biosensors.html).

The current product that falls into this 'wearable category' is the IntelliVue MX40 Wearable patient monitor (see figure 12 b and c). The device has a 12 lead ECG, whilst monitors ST and QT, FAST and SpO2 (http://www.usa.philips.com/healthcare/product/HC865350/intellivue-mx40-wearable-patient-monitor). Patients can be wirelessly monitored at what Philips call the IntelliVue Information centeriX. The move to remotely worn wearable device mirrors the trend identified by the Masimo assessment.

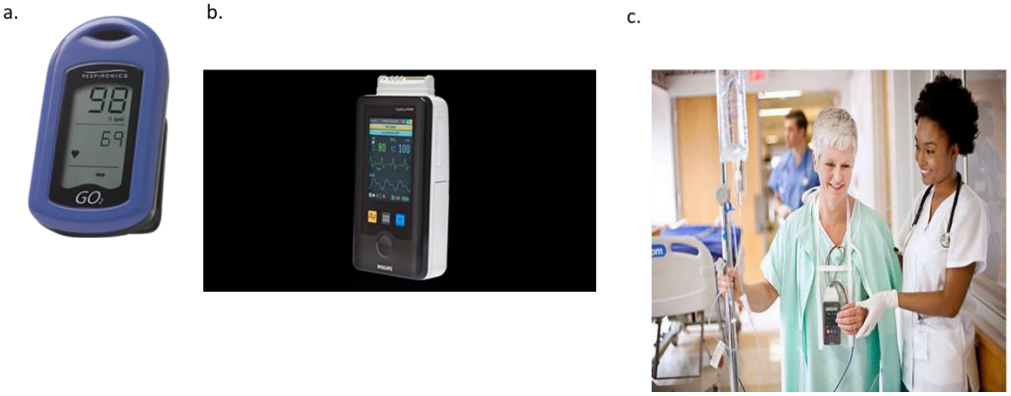


Figure 12: Examples of Phillips technology

A patent assessment for Philips and is summarised in figure 13.

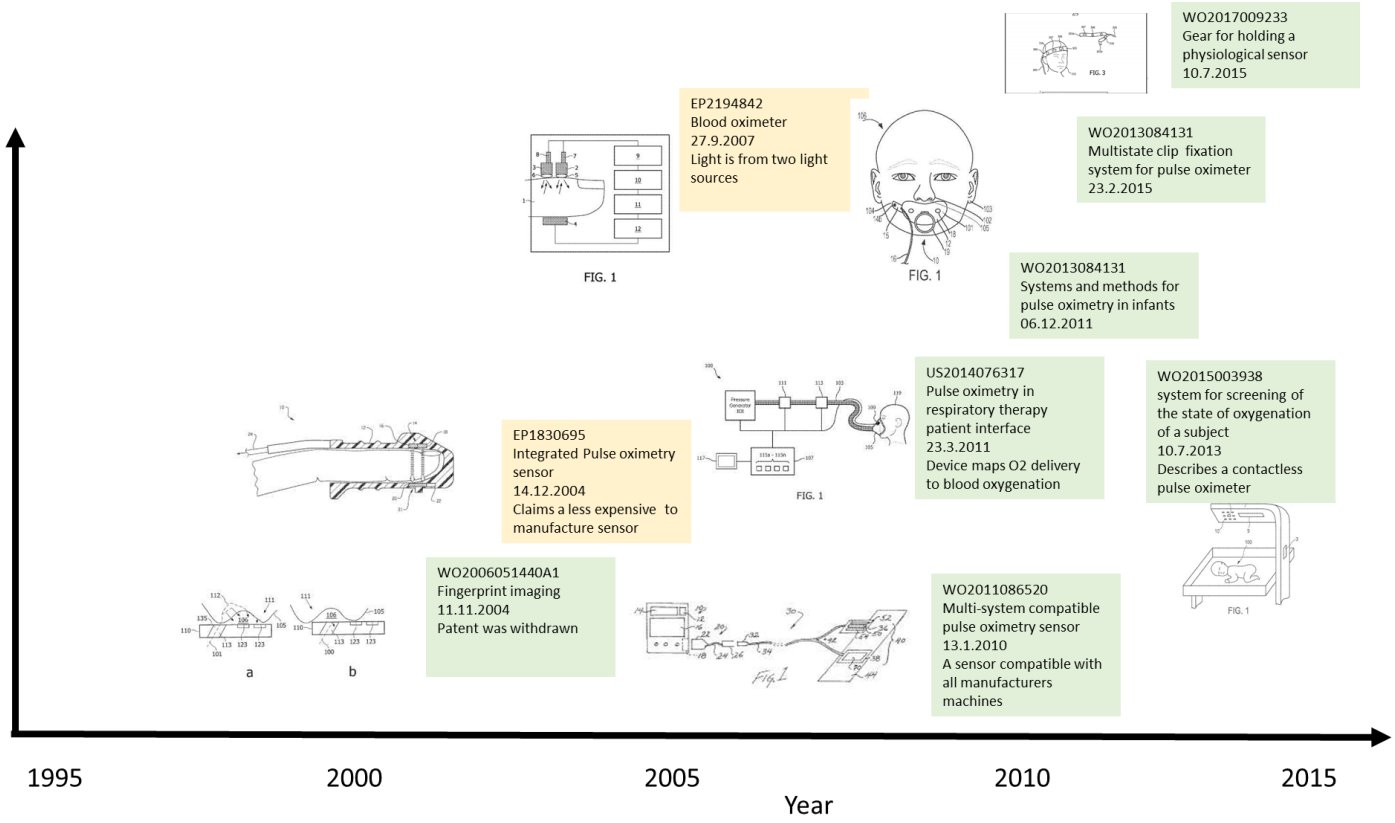


Figure 13: Patent map for Philips related patent. Yellow boxes represent grant patents. Green boxes represent patents that are yet to be granted.

The patents shown in figure 13 show that Philips are actively involved in R&D activities in the oximetry field and their areas of interest include making sensors compatible with all types of oximeter (WO2011086520)r, methods for pulse oximetry in infants (WO2013084131) and novel means of fixation (WO2016135617). Interesting they have also patented method to match O2 delivery to blood oxygen saturation (US2014076317).

The pulse oximetry patent for infants is particularly important for the Viamed project as it discusses a sensor that works via facial tissue. The patent is not yet granted and an initial look at the search report suggests there are issues with novelty over previous IP and that the patent does not constitute an inventive step. Philips might be in dialogue with the International Searching Authority. However as 30 months has passed without the patent entering a national phase it is likely patent has lapsed.

The most recent published patents from Philips describes a compressible clip for attachment of the sensor. Claim 1 of the patent states "wherein the clamping member (26) is configured to attach to the body part by transitioning from a first stable state to a second stable state via a compression force applied to the clamping member". The patent also shows the graphic shown in figure 14 that shows wireless communication and reflects the direction Philips are progressing their monitoring technologies.

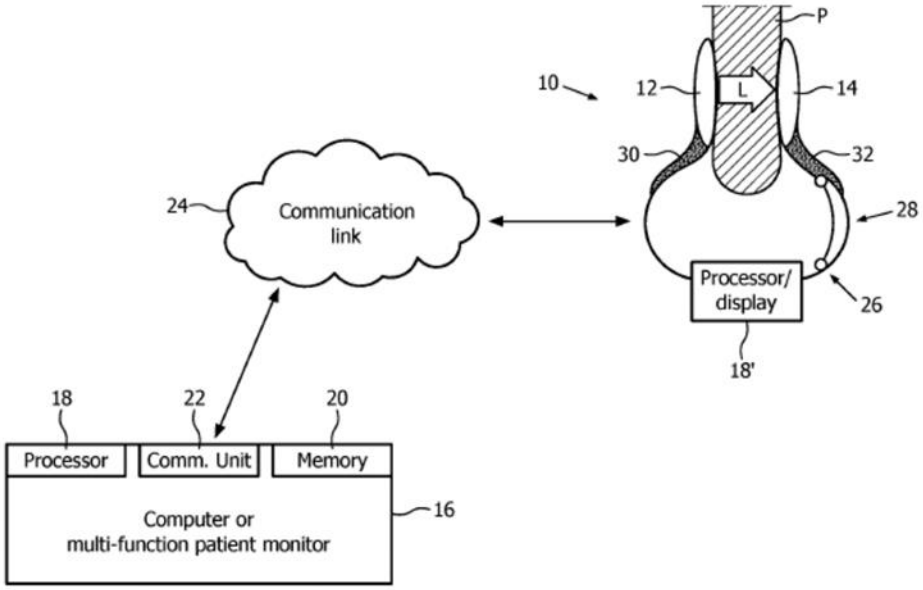


Figure 14: The sensor articulated in WO20161356. The graphic shows how the sensor might be linked to a computer or patient monitor.

A second recently filed patent entitled gear for holding physiological sensor (WO2017009233). The wearable gear being configured to automatically adjust the maximal length such that the predefined tension is obtained regardless of the size of the body part of the subject. This is a headband the company claims improves over the state of the art (described in US7698909) that closure is easier (without practice) and that their disclosure allows a head band of patients with different sizes of head.

Should user needs indicate a preference for a head band type device a more focused assessment of IP around head devices would be required.

One other interesting patent that Philips has filed describes a contactless oximeter that use the principle of remote photoplethysmography (WO2015003938). Photoplethysmography (PPG) an optical measurement technique that evaluates a time-variant change of light reflectance or transmission of an area or volume of interest. This appears to offer a radical approach to oximetry and developments in this area should be monitored.

Philips Respironics summary

Philips are active in the areas of oximetry and their market products show a trend towards wearables and remote monitoring. From an R&D perspective they have several recent patent filings in the sensor area including a sensor that monitors infants via a facial tissue. The progress and patent status of intellectual property held by Philips should be monitored during the duration of the project.

In addition, other Philips devices that they have in the sleep market include sleep quality and movement detection functions. Customer need analysis should determine whether any additional functionality would add value to the device.

3.4. Biochem International (BCI®)/Smiths Medical/

Smiths Medical is a large multinational company with 7600 employees who have products in many medical areas from products that protect health care workers, through to airway management, diagnostics and in vitro fertilisation.

In their strategy they cite that they are investing and are well positioned to take advantage of the ongoing shift in healthcare delivery from hospitals to alternate sites and home care (see https://www.smiths.com/sm-strategy.aspx). The company also claim to be taking the lead in wireless monitoring and they use their SmartX wireless Invasive Blood Pressure monitoring (IBPM) system to highlight this claim.

Smiths market the Biochem International (BCI®) branded oximeters (hence the reason why these two companies are discussed together). There are other distributers such as CNA Medical (http://www.cnamedical.com/BCI.htm). The relationship between Biochem International and Smiths Medical appears to be particularly strong as one of their devices, the BCI® Advisor® Vital Signs Monitor, uses the Advisor® trademark that is registered to Smiths Medical rather the Biochem International.

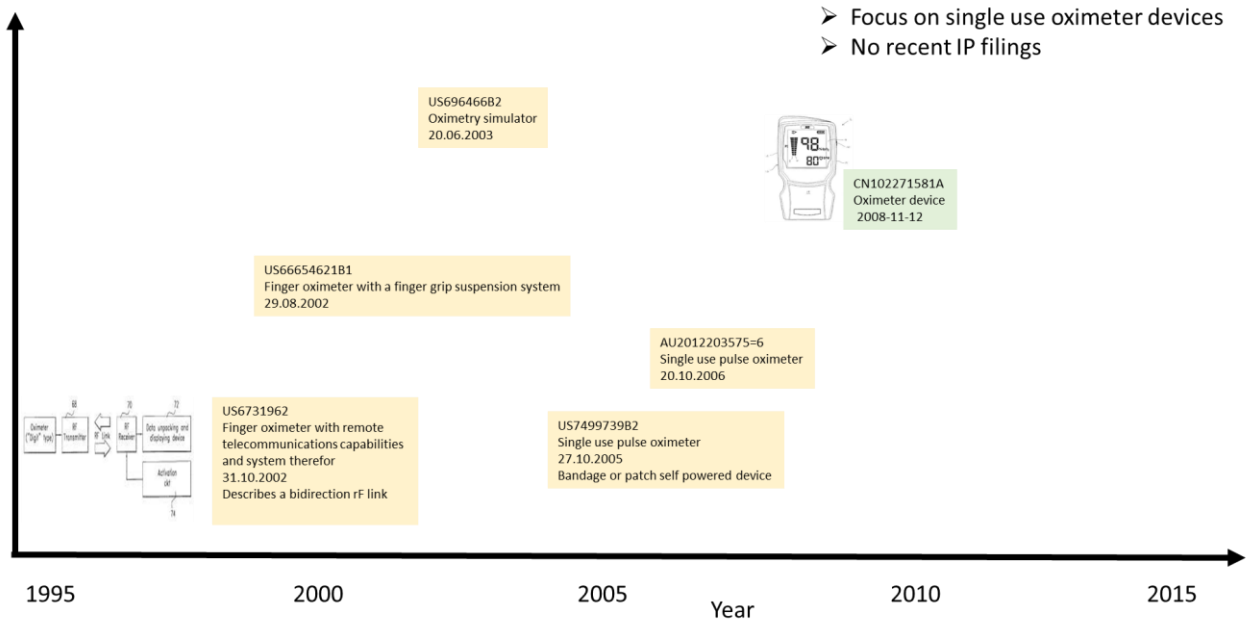
BCI® have a broad range of generic oximeter including finger, desk top and combined function (e.g. capnography) oximeters (see figure 15 for examples). BCI® SPECTRO2™ series 30 and SPECTRO2™ Pulse Oximeter Pulse oximeter claim to continuously monitor in any clinical setting even under conditions of low perfusion or during motion (https://www.smiths-medical.com/products/patient-

monitoring). The BCI® oximeters currently have a range of accessories including neonate, infant, paediatric and adult finger sensors.

Figure 15: Examples of BCI® oximeters and accessories.

A search around "oxygen" and "oximeter" for Smiths Medical identified 35 patents, the majority of these related to ventilation systems. However a number did related to oximeters. These were all filed prior to 2008. Most notable two patents were filed that describes single use oximeters (US and AU2012203576. These are self-powered devices that describes the use of RF bidirectional links as a means of providing the oximeter with remote telecommunication capability.

A search using the terms "oximetry or oxygen" and "Biochem International" identified a single patent that was not considered relevant to the focus of the paediatric oxygen monitoring project. An additional search looking at IP filed by Biochem International identified some relevant IP (US5437275A1 Pulse oximetry sensor", US5558096A "Blood pulse detection method using auto correction". The patent life of these patents has now lapsed and would therefore not impact the freedom to operate.



Biochem International/ BCI

There has been a historical focus on single use oximeter devices. However there has been no recent patent activity suggesting the company is not currently focussing developing new products in this area.

Figure 16: Oximetry patent filings from Smiths Medica

3.5. Nonin Medical

The company market a variety of finger pulse oximeters for the professional market and their colour pulse indicators show a green, yellow or red light that provides a quick assessment of patient pulse quality.

Nonin also market regional oximeters that are designed to measure oxygen delivery to specific tissue such as the brain and spine. These are differentiated from conventional pulse oximeters in that they can deliver both pulse and cerebral oximetry measurements

An example of the types of oximeters they market are shown in figure 17 and shows that with the other big players they are moving in the direction of wearable and wireless technologies.

Figure 17: Nonin oximeter solutions on the market

Nonin also put emphasis in competitor benchmarking. For example, they compare data showing the SpO2 accuracy and precision during movement with the Nellcor (Covidien/ Medtronic) device and two other unnamed pulse oximetry devices (see http://www.nonin.com/Puresat) The data shows the only the Nonin Onyx® II 9550 and Nellcor pulse oximeters accurately tracked the subject's desaturation down to 83-84% SpO2 and back up to 97% SpO2.

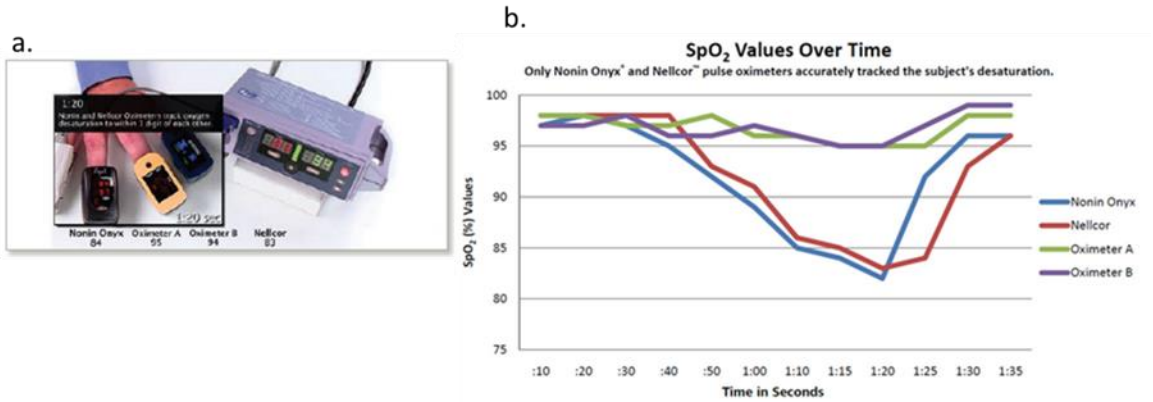


Figure 18: Benchmarking of Nonin oximeters with competitor devices.

Interestingly they claim to market the world's first wireless finger pulse oximeter (the Onyx II Model 9560 with Bluetooth® wireless technology) that allows clinicians to remotely monitor the blood oxygen saturation levels. The unique selling point they use is that "Wireless oximetry gives patients a new level of freedom and control as they go about their daily lives". It is designed for use in the patient's home environment and might therefore be useful as a benchmark device in future. The development of the wireless device reflects their patent strategy focussing on wireless solutions. These patents should be considered in any future strategical and concept decisions from the project team (note there are not granted patents, but patent pending) (see discussion below).

17 patent families were identified with Nonin as an assignee using the search phase "oxygen or oximeter or oximetry". A summary of the main filings since 2005 is shown in figure 19.

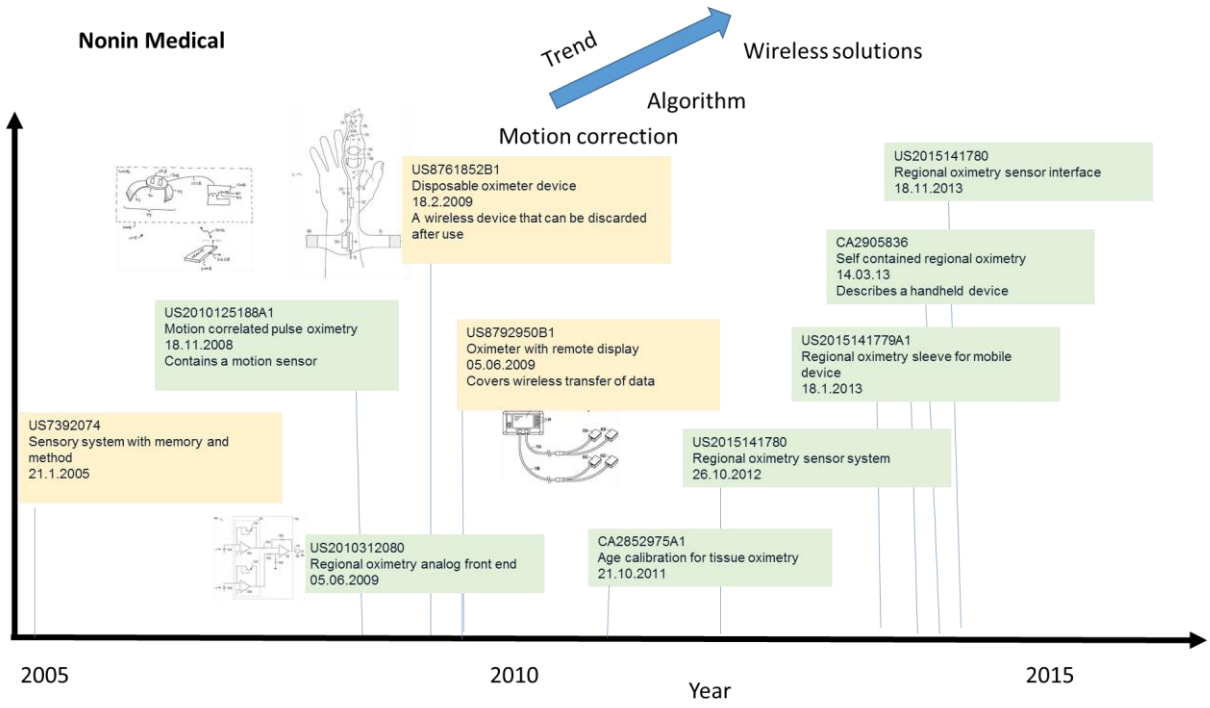


Figure 19: Summary of some of the key Nonin Medical patent filings.

Figure 19 shows that Nonin Medical have increased their R&D efforts and frequency of patent filings in recent years with a clear shift towards wireless devices.

The latest patent the company have filed (US2015141780A1) describes a system to include sensor, a second connector, a local processor, a first telemetry module, a second telemetry module, and a remote processor. The sensor module that can be coupled to a mobile device and manually positioned at a tissue site. The mobile device can display results and can communicate the data to a remote device using wireless communication. This patent application appears important and should be monitored and any search reports issued. A brief search of the legal status revealed the patent had bas been rejected but the company have put in a request for continued examination under 37 CRF 1.114. The legal outcome of this filing will help identify any opportunities or barriers to securing remote sensing IP in the future.

Other patents filed by Nonin Medical describe specific elements, such as US2015141779 that addresses solutions around rapidly established temporary coupling to the tissue and using a mobile computing device. Historical patent filing focus on disposable devices, motion sensors incorporated into the device) and calibration of oxygen saturation.

Although Nonin Medical have been prolific in terms of the number of patent filings in recent years, from the perspective of Viamed these are not necessary important in terms of freedom to operate (within Europe) as most of their filings appear to focus solely on the US (although each patent family should be assessed in more detail to confirm this (there are some that are filed in Japan and the EU).

Interestingly they claim to market the world's first wireless finger pulse oximeter (the Onyx II Model 9560 with Bluetooth® wireless technology) that allows clinicians to remotely monitor the blood oxygen saturation levels. The unique selling point they use is that "Wireless oximetry gives patients a

new level of freedom and control as they go about their daily lives". It is designed for use in the patients home environment and might therefore be useful as a benchmark device in future

Nonin Summary

Noni have had a clear strategy of developing wireless devices over the last few years and this is reflected in the launch of the Onyx® II 9560 wireless oximeter and the filing of several patents in this area. It is unclear at this time whether any of these patents will be granted as initial submissions have been appear to have been rejected. The legal status of these patents needs monitoring during the duration of the project. Significantly the company have focussed on intellectual property protection in the US and as such even if granted these patents might not affect the freedom to operate in Europe (a patent attorney would be required to validate this assumption).

3.6. Covidien/ Medtronic

Medtronic (formally Covidien) market a range oximeters and sensors and use the Nellcor™ brand and are also one of the few companies that market forehead sensors. The company differentiate their sensor technology and call it OxiMax™ Technology, which claims to detect hypoxic events 90 seconds faster. The OxiMax™ digital memory chip is embedded into the sensor that contains all the calibration and operating characteristics. This according to Medtronic gives the monitor the flexibility to operate accurately with a diverse range of sensor designs. In essence the calibration occurs in the sensor and not the monitor. Medtronic claims this feature differentiates their technology from competitors.

The company claims that the device is accurate between 60-100%. However, a closer appraisal shows that in their target range (60-80%) the accuracy is ±3%. Although between 70-100% the pulse oximetry accuracy is 2%. In neonatals at 60-80% the accuracy falls to ±3% and for both adults and children with motion the accuracy at 70-100% is ±3%.

The company do however put emphasis on evidence and there website shows over 300 publications (see http://www.medtronic.com/covidien/products/pulse-oximetry/#about-nellcor

The full range of their oximetry portfolio can be found at http://www.medtronic.com/covidien/products/pulse-oximetry/ and representative examples of current products are shown in figure 20

Figure 20: Representative examples of oximeters and sensors from Medtronic.

One interesting perspective of this product position is that Medtronic market adhesive type sensors, but also market non-adhesive sensors and indicate these for delicate skin. Medtronic claim the adhesive can cause skin trauma. The non-adhesive sensors that are typically soft and pliable form material that fasten with Velcro® eliminating the need for an adhesive. The device is marketed for neonatal patients.

The potential need to avoid skin trauma should be considered as a design input during the concept generation phase of the project and the selection of adhesive, if needed might differentiate the product. For example, in other markets soft silicone type adhesives are marketed as gently and atraumatic to delicate skin.

A patent search using the terms “oxygen or oximetry or oximeter” with “Medtronic or Covidien as the applicant identified 336 patents in the Espacenet world database. In the confines and resources of the review it was not possible to do a detailed appraisal. However an overview of the types of patent with some representative examples is provided in figure 21.

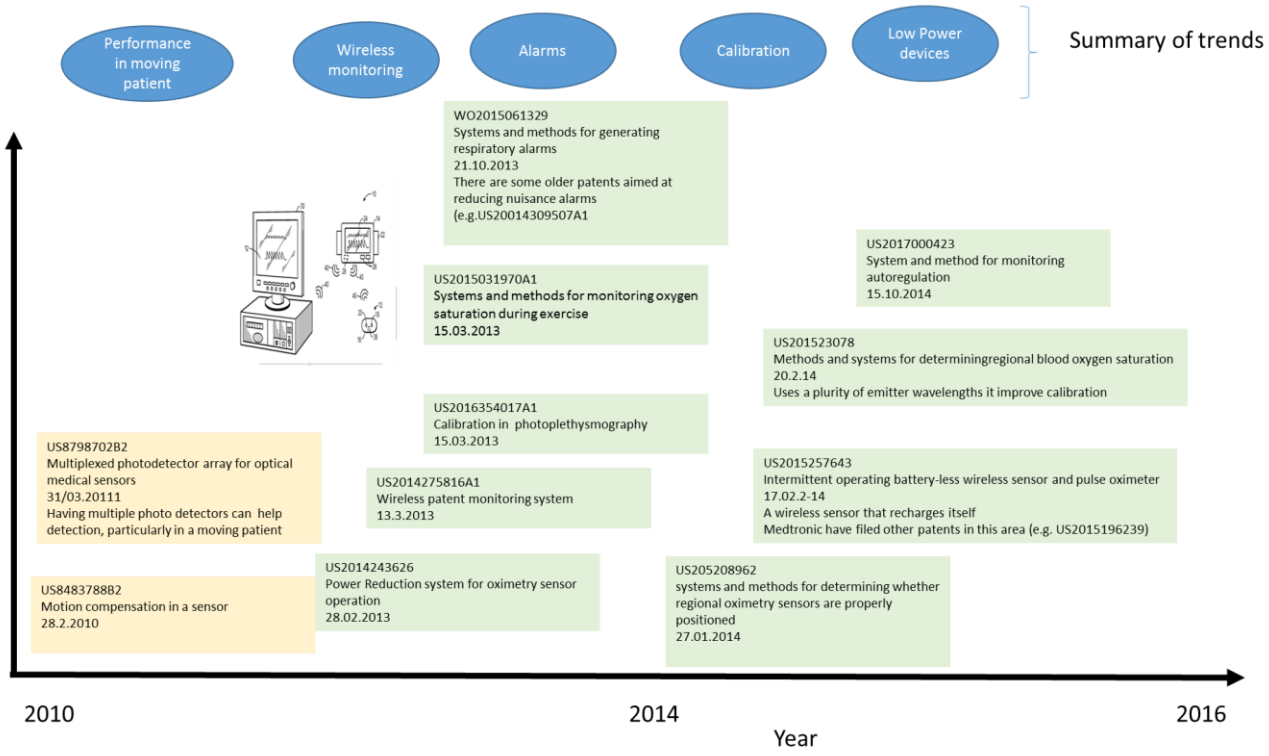


Figure 21: Summery of key Medtronic patent filings.

Medtronic/ Covidien have some older patents that the project team should be aware bout. For the granted patent (but only in the US) US8365730B2 describes a method for a monitor to analyse a plethysmograph and to adjust the ventilator setting based on the oxygen saturation of the patient. In addition as stated above there are a variety of patents describing systems to mitigate interference during oximetry? It is recommended that such patents be examined in more detail should the project team determine solutions aimed at reducing interference, reducing motion artefacts or improving calibration or accuracy.

Covidien / Medtronic summary

Medtronic have filed 336 patents in the area and as such the search was limited to key patents and trends from 2010 to the present day. Recent patent filings cover areas such as performance in moving patents, wireless monitoring, alarms, calibration and low power devices and these should be monitored for legal status and new filings during the duration of the project.

3.7. Konica Minolta

Konica Minolta manufacture a range of oximeters that are marketed by a range of distributers (see figure 22). The Pulsox 1 is indicated for spot checking, the Pulsox 300 device for spot checking and exercise tolerance testing (e.g. 6 minute walk tests) and the Pulsox 300i model is designed for long term monitoring of patient and shows Konica Minolta are moving into the wearable market (see http://www.devilbisshc.com/products/pulse_oximetry/). The Pulsox 300I model has software and can be transferred to a PC via a USB cable (see figure

The devices are marketed in the UK via companies such as Stowood a company that specialises in sleep diagnostics (http://www.stowood.co.uk/Oximeters.html). Devillbiss Healthcare is a second key distributor of Konica Minolta devices (see http://www.devilbisshc.com/products/pulse_oximetry/)

From a patent filing perspective a search of Oximetry, oximeter and oxygen identified over 500 patents, most in unrelated fields to oximetry a refined search looking at “oximetry or oximeter” as search terms with Konica Minolta as the applicant identified 21 patent filings.

Figure 22: Konica Minolta oximeters that are on the market

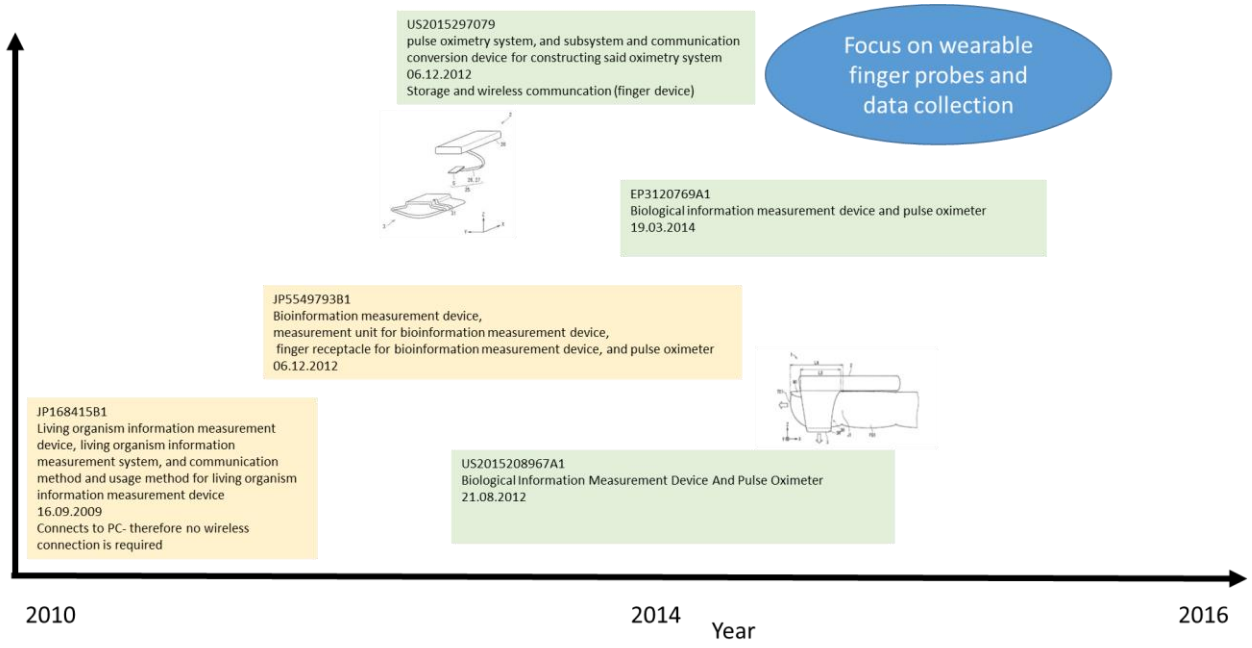


Figure 23: Konica Minolta recent patent filings.

An assessment of recent patent filings shows that the focus of recent activity has been on finger probes, and data collection from the probes. This patent trend reflects the launch of the Konica Minolta Wireless probes as shown in figure 22.

Konica Minolta Summary

There have been 21 patent filings identified by Konica Minolta the most recent ones focus on wearable finger probes, which is reflected in recent product launches such as the Pulsox 300 with wearable probe. The patent activity of Konica Minolta should be monitored and their patent filings should be reviewed prior to future patent filings.

3.8. Other Oximeter manufacturers

Table 1 summarise the results of searches conducted on some of the smaller companies that have a history of manufacturing and selling oximeters.

Table 1: Other companies that manufacture and market oximeters		
Company	**Current oximetry products**	**IP / comments**
Criticare Technologies Incorporated http://www.criticareusa.com/	Manufacture and market monitoring systems. Their most recent oximeter is the SEQUEL™ Pulse Oximetry model which the company claim is the first completely digital solution providing high performance through patient movement and low perfusion conditions.	The company seek partnerships for research and OEM partnerships. 6 patent families identified all are expired patents from the 1980's and 1990's Areas covered in historical patients include digital oximeters and method for calculating oxygen levels, foetal sensor devices and a combined ECG- pulse oximeter.
Delbio Inc. http://www.delbio.com.tw/AboutUs.htm	Delbio is a Taiwanese branch biotechnology company belonging to Delta Electronics groups and manufactures a range of handheld and fingertip oximeters. These are not differentiated compared to other products cited in this review. Compared to some of the competitor companies they have a limited offering with one handheld model and three fingertip oximeters. In this test they used an induced hypoxia model in which 11 volunteers with different skin tones were assessed. Data was collected on a minimum of 250 data points between 70-100% SpO2	At the time of the search (6th Feb 2017) the company has 27 published patents 4 of which are related to oximetry. These patents are limited to China and Taiwan.

	for the 11 subjects. The results demonstrated a good correlation between the devices.	
Spencer http://www.spencer.it/en/products	Spencer are an Italian R&D company that develop products for emergency services. They market one fingertip pulse oximeter that is similar to standard devices on the market.	No oximeter related patent filings from Spencer were identified during a patent search.
Stowood	Stowood area an Oxfordshire based company who specialise developing products to support the diagnosis of sleep and breathing disorders. Since 1994 they have been marketing oximetry software for the home environment that can be used on multiple makes of oximeter. Stowood do not manufacture their own oximeter but distribute the Konica Minolta devices.	Stowood have not filed any oximeter related patent filings.

4. Technical search

There are numerous companies developing wearable technologies. It is too early in the project to do detailed searches as the potential for defining an 'inventive' step needs to be defined. However this section is designed to give an overview of the technology trends that other individuals and organisations are developing in the oximetry related. There are over 1200 patents (including rejected, patent pending and granted patents) with the word "oximeter" in the title and as such a detailed assessment could not be conducted in the focus of the review. However a broader more detailed assessment should be conducted in phase II of the project.

However a search using the terms "oximeter" and chest identified a number of relevant patents. The granted patent "EP2214551B -Measurement of oxygen saturation of blood haemoglobin" describes a chest based oximeter for measuring oxygen saturation. A search of the history however revealed that of the majority of the claims have been rejected in the US. The patent examiner did conduct a telephone interview with the company on 4th January 2017 in which they argued patentability over prior art that was identified in the examiner's report. The argument for patentability appears to be based on the use of hydrogel at the interface. This highlights the need to conduct further analysis during the project. The company that filed the patent are a Belfast based company called Intelesens that focus on developing and perfect intelligent, wireless, vital signs monitoring and screening technologies (see http://intelesens.com/). This includes a device that measure ECG, heart and respiration rate. The company do not appear to have an oximetry solution as their web page suggests that their technology can be used in conjunction with existing oximetry monitoring solutions. However the effort the company are putting into securing US patent suggests that they are developing

novel wireless systems for oximetry that could offer a disruptive technology, and as such this company should be closely monitored.

The patent search also identified a company "Everyone Care Technologies" that is focussed on wearable solutions for sports and clinical market and paediatric markets is an area of focus. Their web site highlights the direction of their focus that included developing oximeters with added functionality as products for the early warning of sepsis. The patent "WO2015168235 Physiological sensors, systems, kits and methods therefor" describes solutions for placement on the chest, upper arm or abdomen. The patent is filed and has not yet been granted. It is also only current published in the US.

Patent "EP28834498-Oximeter for neonate" filed by describes a clamp type device that is essentially a rod that the hand needs to grasp as part of sampling process.

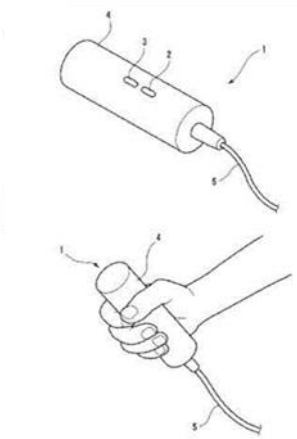


Figure 24. An example of a new potentially disruptive sensor approach for neonatals.

There are numerous patents referring to wrist worn devices, wireless and as the project progresses provision should be made for additional focussed searches to be conducted.

The above patents are intended to provide a representative indication of the types of patent that are currently being filed in the area of oximetry. However one should be aware that non-contact video based technologies could supersede the use of sensors (see Tarassenko *et al*, 2014 (https://www.ncbi.nlm.nih.gov/pubmed/24681430). This example if perhaps not suitable of home monitoring, but it does highlight the need to monitor other solutions.

There are other oximeter products that are in development that can be identified in the literature and /or internet. For example, developing oximeters appears to be popular topic for academic based projects. For example Rutgers University have published on the design of a low cost, portable pulse oximeter for monitoring applications. Their solution has three components 10 optical sensor; 2) microcontroller and 3) mobile phone app that works by Bluetooth. They claim to have made a prototype for less than $50 (see http://www.ece.rutgers.edu/files/capstone/capstone2014/Oximeter/Capstonefinalreport.pdf).

Worcester Polytechnic Institute conducted a project on a sensor strapped to either the wrist or chest and claim that they could achieve a SpO2 accuracy of ±1.0%. Worcester Polytechnic Institute have filed some patents in the area of motion and noise reduction (e.g. WO2016123484A1) showing that universities are also working in the oximetry area.

One new trend is the use of non-traditional parts of the anatomy to be used. The chest is one of these sites that appears to be receiving recent attention. In a non-peer reviewed article on Linked in Mody Shalaby, a freelance biomedical engineer describes experimental data that taking measurements from the chest correlates with that from a finger arguing that the chest offers a good sampling site. In addition the data shows that when the sensor is placed on the chest it detects the drop of SpO_2 15 seconds quicker than the finger. The author claims that this earlier diagnosis would enable the clinician to introduce treatment more quickly in an emergency. Both sets of readings were taken using Nonin evaluation kits (see figure 25)

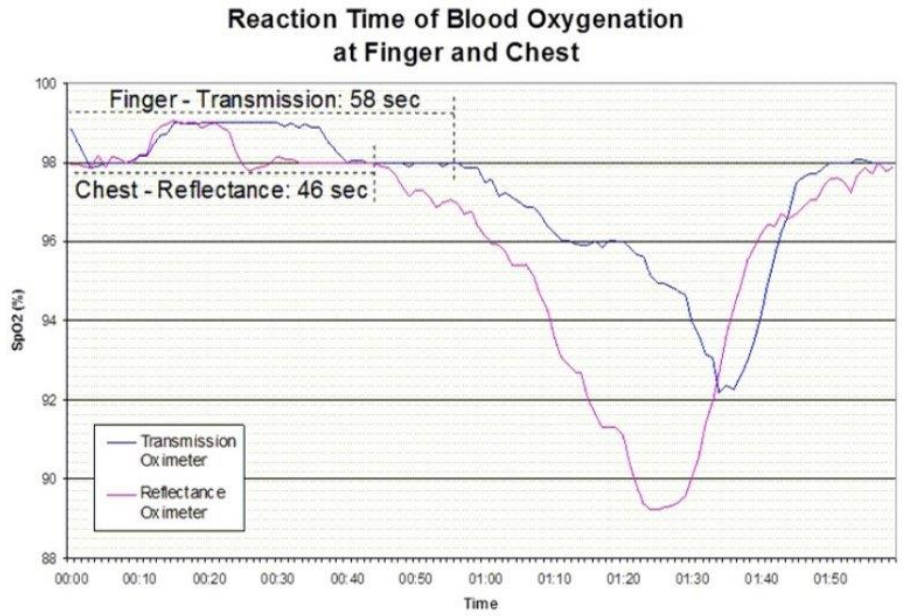


Figure 25: Oximetry readings taken simultaneously from the chest and finger (taken from

https://www.linkedin.com/pulse/blood-oxygen-level-measurement-chest-based-pulse-oximetry-shalaby)

This data above is not validated but it does highlight the possibility that the ideal probe site might not necessarily be one of the sites conventionally used.

In summary, the data shows there is a clear drive to wireless devices and remote monitoring and that while there is activity around calibration and noise reduction the design and placement of sensors might offer an avenue to reduce artefacts while generating strong IP.