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# Comparison of iCARE Tonometer with Pulsair and Tonopen in Domiciliary Work

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## Introduction

Traditionally, intraocular pressure (IOP) has been measured by applanation of the cornea, using a topical anaesthetic, or by non-contact tonometry (NCT), using a puff of air on to the cornea.

Recently a new type of contact tonometer has been made available: the iCARE is a rebound tonometer that does not require the use of an anaesthetic. Rebound or dynamic tonometry is based on making a moving object collide with the eye, and the motion parameters of the object are monitored following contact.

Measuring the IOP in a domiciliary environment can be difficult; it was therefore decided to compare this new instrument with the two tonometers most commonly used by domiciliary companies – the Tonopen and the Pulsair. These instruments are used since they allow IOP measurements to be obtained in an objective manner, as does the iCARE. Instruments such as the Perkins, which require a subjective assessment, are less common in domiciliary practice.

## Description and Use of Instrument

The iCARE tonometer is a hand-held instrument of a similar weight to the Tonopen. It uses a small probe that makes contact with the eye very briefly, so that there is no need for a topical anaesthetic. A new probe is used for each patient (Figure 1).

The probe has a round tip of 0.9mm radius and it weighs 26.5mg. The other end of the probe is metallic, and it is held in place in the tonometer by a magnetic field that is activated when the measurement button is pressed.

The reading is performed by placing the adjustable rest on the patient's forehead, so that the probe is 4–8mm from the cornea. Once the measurement button is pressed, the tip of the probe hits the central cornea. The microprocessor analyses the deceleration of the probe following the impact; deceleration is less at low than at high IOPs and, consequently, the higher the IOP, the shorter the duration of the impact. The manufacturer recommends six consecutive measurements; after each measurement there is a short 'beep'. After the six measurements, the IOP is shown on the display preceded by a letter 'P', with an indication of the reliability of the measurement (*iCARE User's and Maintenance Manual*):

- If the P is static, the reading is of the highest reliability
- If the P is blinking, then the standard deviation of the measurements is greater than normal
- P_ (line down): the standard deviation of different measurements is slightly greater than normal, but it is unlikely to have a relevant effect on the result
- P– (line central): the standard deviation of different measurements is clearly greater than normal; the effect is unlikely to be relevant, but the manufacturers recommend another reading if the IOP is more than 19mmHg
- P¯(line up): the standard deviation of the different measurements is too great and another measurement is recommended

*Figure 1. iCARE tonometer.*

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In addition to the reliability indication, the instrument will interrupt the reading if the probe does not hit the cornea at the correct speed or from the correct distance. Two beeps will be heard, and an error code will be displayed. The seven error codes are listed in the instruction manual; eg E01: the probe did not move.

Error codes are rarely displayed when an experienced practitioner uses the instrument.

## What was the Purpose of the Trial?

Healthcall is a domiciliary service, and a high proportion of patients seen suffer from dementia. This means that patient cooperation can be poor, so tonometry is sometimes very difficult, and occasionally impossible, to perform. Patients with learning disabilities, multiple sclerosis, Huntington's chorea and other debilitating conditions are regularly examined, and many of these are unable to comply with the usual methods of tonometry. Instillation of anaesthetic drops or the impact of a puff of air has been known to cause great distress to some of these patients, and so this trial was undertaken to determine:

- whether a greater number of successful tonometry readings could be obtained with the new instrument
- how the measurements obtained compared with those from the usual tonometers (Pulsair and Tonopen)
- the practitioner's perspective
- the patient's perspective

## Method

Specialist Optical Services of Gateshead and Tiolat oy, the Finnish manufacturers of the instrument, provided three iCARE tonometers along with probes for the trial.

One practitioner compared the Pulsair and iCARE on 192 patients (384 eyes: group 1). Two practitioners compared the Tonopen and iCARE, one using 0.4% benoxinate hydrochloride as the topical anaesthetic on 102 patients (group 2), and the other using 0.5% proxymetacaine hydrochloride on 121 patients (group 3) (446 eyes altogether). The choice of instrument and anaesthetic reflects the personal preference of the practitioners involved.

When comparing with the Tonopen, the iCARE was always used first in order to ensure that the topical anaesthesia had no effect on the results, since it has been shown that the instillation of topical anaesthetic can lower the IOP measurement obtained (Badouin & Gastaud 1994). Anaesthetic drops were transported in a cool-box.

All practitioners included in the study were fully conversant with the instruments they used, and all instruments had been serviced and calibrated. Readings were obtained in accordance with the manufacturers' recommendations in all cases, i.e. four consecutive Pulsair readings, and measurements within normal standard deviation for the iCARE and Tonopen.

All measurements were taken in a domiciliary setting and with the patient in a seated position, although all three instruments can be used with the patient supine if necessary.

The data collected for each instrument included:
- patient age
- Pulsair/Tonopen reading for the right eye
- iCARE reading for the right eye
- Pulsair/Tonopen reading for the left eye
- iCARE reading for the left eye
- comfort level for the Pulsair/Tonopen
- comfort level for the iCARE
- number of failed readings for each instrument
- comments

A measurement was considered to be unsuccessful if it was not possible to obtain the number of readings recommended by the manufacturer:

- Pulsair: four readings using the 'average' function
- Tonopen: sufficient readings to give an average, indicated by the instrument beep, and falling within normal standard deviation, as indicated by the instrument display
- iCARE: six readings, falling within normal standard deviation, as indicated by the instrument display

Comfort levels were recorded using the following scale:

| | |
|---|---|
| 0 | no discomfort |
| 1–2 | slight discomfort |
| 3–4 | moderate discomfort |
| 5 | severe discomfort |

This scale is a subjective measurement of the patient's experience and was used where the patient was sufficiently able to comment.

## Results

As expected in an elderly population, more female patients (75%) were seen than male patients (25%).

*Table 1 Results for iCare compared with Pulsair and Tonopen*

| | Group 1 | | Group 2 | | Group 3 | |
|---|---|---|---|---|---|---|
| | **iCARE** | **Pulsair** | **iCARE** | **Tonopen (benoxinate)** | **iCARE** | **Tonopen (proxymetacaine)** |
| **Age (years)** | | | | | | |
| Average | 81 | 81 | 83 | 83 | 83 | 83 |
| Range | 34–101 | 34–101 | 55–98 | 55–98 | 50–98 | 50–98 |
| Median | 84 | 84 | 84 | 84 | 84 | 84 |
| **Discomfort** | | | | | | |
| Average | 0.8 | 1.7 | 0.15 | 0.85 | 0.01 | 0.2 |
| Range | 0–4 | 0–5 | 0–2 | 0–3 | 0–1 | 0–2 |
| Median | 1 | 2 | 0 | 1 | 0 | 0 |
| **Failure** (number of eyes) | 32/384 8.33% | 191/384 49.7% | 12/204 5.88% | 39/204 19% | 3/242 1.24% | 81/242 33.47% |

Table 1 summarises the data collected for the three study groups.

Bland & Altman plots of the results are shown (Figures 2–5), since this is now considered to be a more appropriate method of results analysis than the traditional use of correlation coefficients (Bland & Altman 1986).

Table 2 shows the agreement between the instruments.

*Table 2. Agreement between iCARE and Pulsair and Tonopen*

| | **Group 1 iCARE/ Pulsair (%)** | **Group 2 iCARE/ Tonopen (benoxinate) (%)** | **Grop 3 ICARE/ Tonopen (proxymetacaine) (%)** |
|---|---|---|---|
| Identical measurement | 34.8 | 14.7 | 13.75 |
| Within ± 1mmHg | 72.7 | 38 | 41.25 |
| Within ± 2mmHg | 90.9 | 63.1 | 63.1 |

## Discussion

The Tonopen results from the two practitioners were analysed separately, since they were from different groups of patients, and also because it is known that proxymetacaine stings less than benoxinate, and it was expected that this might have some effect on the success rate obtained with the Tonopen.

### Were a greater number of successful readings obtained with the iCARE?

Readings in accordance with the manufacturers' instructions were obtained in 50.3%, 81% and 66.53% of eyes using the Pulsair, Tonopen (benoxinate) and Tonopen (proxymetacaine) respectively. The success rate for the iCARE overall was 94.34%.

There were no cases where either the Pulsair or Tonopen succeeded and the iCARE failed, but there were 159 eyes for the Pulsair where the iCARE obtained a successful reading and the Pulsair did not, and for the Tonopen there were 105 eyes where the iCARE was successful but the Tonopen was not.

In one case where a measurement was not possible with the Tonopen but was obtained with the iCARE, the patient was referred with raised IOP. This was a patient in whom visual field analysis and detailed ophthalmoscopy were not possible due to an inability to cooperate because of

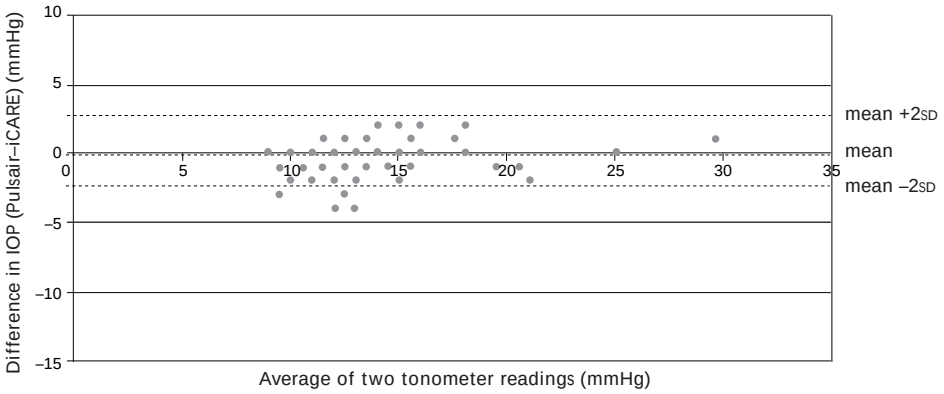


*Figure 2. Bland & Altman plot showing Pulsair/iCARE results for the right eye.*

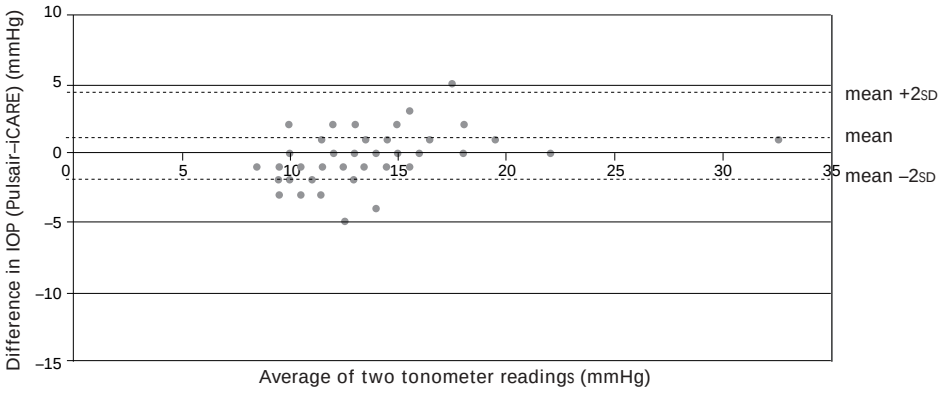


*Figure 3. Bland & Altman plot showing Pulsair/iCARE results for the left eye.*

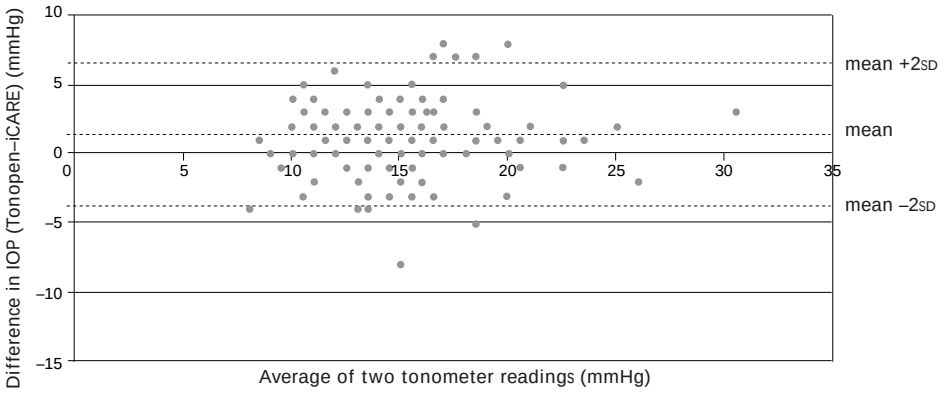


*Figure 4. Bland & Altman plot showing Tonopen/iCARE results for the right eye.*

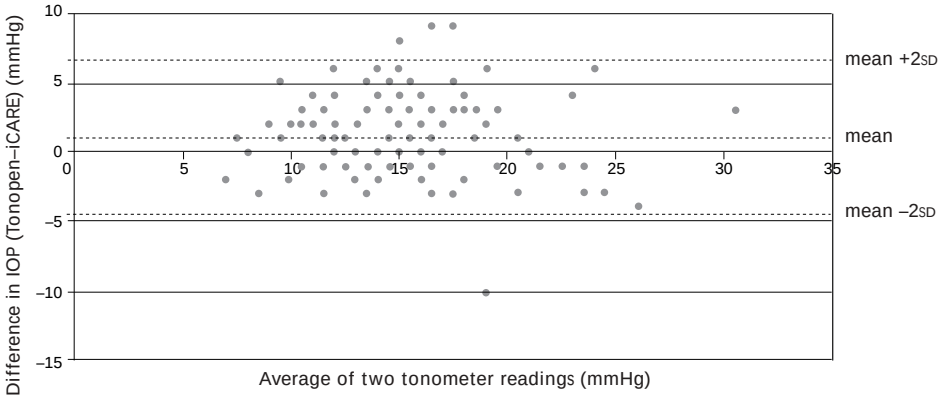


*Figure 5. Bland & Altman plot showing Tonopen/iCARE results for the left eye.*

dementia, and, without the iCARE, the IOP would not have been obtained either. This fact alone is perhaps an indication that the iCARE tonometer is highly suitable for domiciliary work.

The most common reason for failed readings with the Pulsair was poor fixation (52%). In some cases it was possible to obtain a Pulsair reading consisting of one single pulse of air, but not the recommended four readings to obtain an accurate average. In this trial we were only using readings obtained in accordance with the manufacturers' instructions for all three instruments involved, and so these individual pulses were classed as failures.

The main reason for failure to obtain a reading with the Tonopen was lack of cooperation due to dementia (86.7%); seven of these patients refused to have the drops instilled, and in the case of four eyes, corneal scarring prevented a measurement with the Tonopen, but not with the iCARE.

As mentioned previously, a large percentage of the patients seen by Healthcall have dementia to some degree, and many are not able to follow simple instructions, with the result that the Pulsair was unsuccessful. The iCARE does not rely as heavily on patient compliance or understanding, and so, it can be used more successfully than the Pulsair for those house-bound patients who have dementia.

Of the patients upon whom the iCARE was unsuccessful, all were due to advanced dementia where patients either would not or could not keep their eyes open for the pressure measurement.

In two cases of Parkinson's disease, where it was not possible to obtain a reading with the Pulsair because of tremor, a reliable result was obtained with the iCARE.

Four of the Pulsair failures were patients who were registered blind, and so could not fixate at all. The IOPs of these patients were measured successfully with the iCARE. There were two cases of irregular cornea due to scarring with which the Pulsair failed to obtain a measurement and the iCARE succeeded.

It is therefore shown that a greater number of successful tonometry readings were obtained with the iCARE than with either the Pulsair or the Tonopen.

## How did the measurements obtained compare with those from the Pulsair and Tonopen?

As shown in Table 2, of the eyes where readings were obtained with both Pulsair and iCARE, 34.8% had identical IOP measurements with both the Pulsair easy eye and the iCARE, 72.7% had readings within ±1mmHg and 90.9% had readings within ±2mmHg. Of the eyes where readings were obtained with both Tonopen and iCARE, disregarding anaesthetic used, 14.24% showed identical readings; 39.62% showed readings within ±1mmHg and 63.1% showed readings within ±2mmHg. These figures are for the overall Tonopen result, since it can be seen from Table 2 that the use of the different drops did not seem to affect the outcome. These results appear to show a closer agreement between readings from the iCARE and Pulsair than those between the iCARE and Tonopen. Nothing significant was found to explain the outlying results. Figures 2–5 show these comparisons of data on an individual basis and further illustrate the closer agreement of iCARE and Pulsair than iCARE and Tonopen.

Previous studies have compared the tonometers used in this study with the Goldmann. A study comparing the Tonopen and the Goldmann tonometers (the Goldmann is the instrument commonly used by ophthalmologists, and taken to be the 'gold standard' for modern tonometry: Frenkel *et al.* 1988) concluded that the Tonopen tends to overestimate at low IOPs (<9mmHg) and underestimate at higher IOPs (>30mmHg). This finding may be a cause for concern to some practitioners. This study also found 63% of the Tonopen readings to be within ±2mmHg of the Goldmann readings.

In comparisons between the Goldmann and the Pulsair, the standard deviation between readings has been shown to be only 1.1mmHg (Parker *et al.* 2001), suggesting that the Pulsair is more likely to give a reading similar to that of the Goldmann than is the Tonopen.

A previous study (Kontiola & Puska 2004) comparing the iCARE to the Pulsair 3000 found that the two tonometers were within ±1mmHg in 52.5% of the measurements and within ±2mmHg in 71.7%. As already noted, the Pulsair has been shown to have a closer agreement to the Goldmann than that of the Tonopen to the Goldmann. It could be assumed from this that a close agreement between measurements from the iCARE and Pulsair would indicate a favourable comparison of the iCARE with the Goldmann. Indeed, one study (Kontiola 2003) comparing the iCARE to the Goldmann found that 55% of the readings were between ±2mmHg and 75% were between ±3mmHg from the mean of the Goldmann readings.

These figures suggest that a note of the instrument employed to take the IOP measurement should always be made on the patient record, and, if possible, the same instrument should be used at subsequent examinations. Variations between types of instrument may falsely indicate a rise in the IOP, since, as is shown on the Bland & Altman plots, in some cases the difference between measurements with different instruments can be over 5mmHg, which would be clinically significant if different instruments were to be used on right and left eyes of the same patient.

### Practitioner experience

The iCARE was considered by all of the optometrists involved in this clinical trial to be easier to use than either the Tonopen or the Pulsair. For domiciliary work, the Pulsair is both bulky and heavy to transport, making the Tonopen preferable to the Pulsair. In addition, many patients express a dislike of 'that puff of air'; in fact, it was reported that one patient had remarked: 'spit in my eye again and I will hit you' in response to the Pulsair being used to measure her IOP!

While it may be preferable in terms of weight and size, the Tonopen requires instillation of anaesthetic drops, and this alone could sometimes cause patients to refuse to allow the IOP measurement to be taken. Proxymetacaine seemed to be preferred to benoxinate, but should be refrigerated, and this is largely impractical in domiciliary work.

The iCARE combines the good points of both instruments. There is no requirement for drops to be instilled, and yet it is small, light-weight and easily portable.

No negative points were found on using the iCARE; the disposable probes cost much the same as the Tonopen tips, and, since no minims of topical anaesthetic are needed, it will be cheaper to use in the long term. The purchase price of the iCARE is similar to that of the Tonopen, much less than the Pulsair, and it does not require expensive servicing and regular calibration, since the manufacturers claim that the microchip technology that operates it is extremely accurate.

### Patient experience

As expected, the results of the relative discomfort when considering the Tonopen were dependent on the anaesthetic used. In the case of the benoxinate (group 2), the average discomfort reported, using the scale described previously, was 0.85. When proxymetacaine was used (group 3), this result was reduced to a discomfort score of 0.2 (an overall result of 0.52 when disregarding anaesthetic).

When the iCARE was used the overall average discomfort experienced by the patients in groups 2 and 3 who were able to indicate it was 0.08.

For the Pulsair the average discomfort was scored as 1.7 (group 1). For the iCARE measurements on these patients the average discomfort was scored as 0.8.

Quite why the group 1 patients should score the iCARE as being 10 times less comfortable than the group 2 and 3 patients is difficult to establish. Nevertheless, these results show that, overall, the patients' experience was that the iCARE was a more comfortable instrument with which to have IOP measured than either the Pulsair or Tonopen.

## Conclusion

The IOP readings obtained using the iCARE tonometer seem to be in closer agreement with those obtained when using the Pulsair Easy Eye, and less so with those obtained when using the Tonopen XL. Interestingly, it has been shown that the Pulsair agrees more closely with the Goldmann tonometer, which is considered by some to be the gold standard in tonometry, than does the Tonopen (Parker *et al.* 2001).

It should be noted that the impact of variation in corneal thickness has not been assessed with the iCARE.

When using the iCARE tonometer, it is possible to obtain IOP readings for patients where both Pulsair and Tonopen fail, particularly when examining elderly patients who have dementia, who make up a large proportion of the patient base serviced by a domiciliary company. It is also easy to transport, which is important for domiciliary work.

The iCARE is very easy to use since less patient cooperation is required than when using either the Pulsair or the Tonopen.

Patients find that when an iCARE tonometer is used IOP measurement is far less uncomfortable than when using either a Pulsair or a Tonopen.

Healthcall Optical Services will be replacing Pulsairs and Tonopens with iCARE tonometers when their existing equipment comes to the end of its useful life.

## Acknowledgements

Thanks to Specialist Optical Services for supplying the original instrument, and particularly to Paul Christian for support during the trial; Antti Kontiola and Tiolat oy for supplying the further two instruments and for providing research material; Peter Tait and David Goldsworthy for their assistance in performing the trial and recording results; Jayne Rawlinson MD, Healthcall Optical Services, for her support and encouragement, and to all my colleagues for listening to my tonometry obsession.

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## Multiple Choice Questions

This paper is reference c938. One credit is available. Please use the inserted answer sheet. Copies can be obtained from Optometry in Practice Administration, PO Box 6, Skelmersdale, Lancashire WN8 9FW. There is only one correct answer for each question.

1. Which of the following statements about the iCARE tonometer probe is incorrect?
(a) The probe deceleration is less at low than at high IOPs
(b) The higher the IOP, the shorter the duration of the impact
(c) The microprocessor analyses the acceleration of the probe
(d) The tip has a radius of less than 1mm

2. Considering the result displayed by the instrument, in which of the following cases is it recommended that another measurement is taken?
(a) P‾ (line up) IOP 15mmHg
(b) P_ (line down) IOP 25 mmHg
(c) P– (line central) IOP 18mmHg
(d) P (static) IOP 28mmHg

3. With which instrument was the highest failure rate recorded?
(a) iCARE
(b) Tonopen/benoxinate
(c) Pulsair
(d) Tonopen/proxymetacaine

4. What was the most common reason for failed readings with the Tonopen?
(a) patient refused drops
(b) poor fixation
(c) corneal scarring
(d) dementia

5. Which statement about the previous studies comparing the Tonopen and the Pulsair to the Goldmann is incorrect?
(a) The Tonopen tends to underestimate at high IOPs
(b) The Tonopen is more likely to give a similar reading to that of the Goldmann than is the Pulsair
(c) The Tonopen tends to overestimate at low IOPs
(d) 37% of Tonopen readings are not within ± 2mmHg of the Goldmann readings

6. What was the overall discomfort rating of the Tonopen in groups 2 and 3 disregarding the anaesthetic used?
(a) 0.85
(b) 0.2
(c) 0.08
(d) 0.52