Spatial Localization after Different Types of Retinal Detachment Surgery

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PURPOSE. To compare the effect on spatial localization of two different forms of surgery for primary rhegmatogenous retinal detachment.

METHODS. Two groups of 30 patients (one group undergoing conventional vitreoretinal procedures, the other undergoing vitrectomy procedures) were recruited. They pointed at targets appearing on a computer touchscreen without being able to see their hands, while viewing targets with the non-surgically treated eye. The sizes of the horizontal pointing errors were recorded on three separate occasions: before surgery, on the first postoperative day, and approximately 10 days later.

RESULTS. On the first postoperative day a significant change in localization of $2.9 \pm 0.9^\circ$ (SD) was observed in the scleral-bucking group, compared with $1.3 \pm 0.6^\circ$ in the vitrectomy group. These changes resolved by the second postoperative assessment.

CONCLUSIONS. These results, particularly in patients in the scleral-bucking group in whom greater manipulation of the extraocular muscles inevitably occurs, are consistent with an alteration in the extraretinal eye position information that is used in spatial localization. This is likely to be a consequence of modified efference copy and/or extraocular muscle proprioception. (Invest Ophthalmol Vis Sci. 2001;42:1495–1498)

The ability to locate the position of objects in the surrounding visual world (spatial localization) is an important aspect of normal visual function. For this to occur with precision the brain must know the direction in which a person is looking, and it depends to a large extent on visual (i.e., retinal) input for this information. However, because the eyes are able to move within the orbits, retinal information by itself is not adequate to specify this visual direction. Further nonvisual (i.e., extraretinal) information regarding the position of the eyes is required to interpret the retinal data and thus determine the direction of gaze. It is believed that this extraretinal eye position information is obtained from two distinct extraretinal sources: monitoring of the motor command sent to the extraocular muscles (efference copy or corollary discharge) and extraocular muscle proprioception. However, the relative contribution of each has been an issue of great controversy for many years.

The task of pointing at targets in surrounding space is an established method for assessing spatial localization, particularly if subjects are unable to see the pointing hand. Integration of the retinal and extraretinal information from the sources outlined in the prior paragraph enables the location of the object of interest to be determined with accuracy. To reach out, or point to this object, an appropriate motor command is sent to the arm and hand, which allows the efficient performance of the task. Patients who undergo conventional scleral-bucking surgery for retinal detachment have been shown to make errors when asked to perform such tasks of spatial localization, while viewing targets with the surgically treated eye. These changes are attributed to alterations in extraocular muscle proprioception, as a consequence of the perioperative manipulation of the muscles.

However, the visual information available to these patients in the immediate postoperative period (i.e., acuity and field of vision) must also have altered. This is likely to contribute more to these errors than the change in proprioception. A more interesting finding is the postoperative localization shifts found in 4 of 10 of these patients when they were tested while viewing with the fellow non-surgically treated eye. It is reasonable to assume that under these circumstances, modified extraocular muscle proprioception from the surgical eye influences the central interpretation of gaze direction, particularly because it is known that eye position information from both eyes is used for this very purpose. If this were the case, then patients who undergo retinal detachment surgery that does not directly involve manipulating the extraocular muscles (i.e., vitrectomy) would not be expected to demonstrate any localization changes after surgery when viewing with the fellow nonsurgical eye. To test this hypothesis a comparison of the effect on spatial localization of two different surgical procedures for primary rhegmatogenous retinal detachment—conventional external scleral-bucking surgery and vitrectomy—was made.

METHODS

All procedures conformed to the Declaration of Helsinki for research involving human subjects. Ethics committee approval was obtained, and informed consent was given in all cases. This was a comparative nonrandomized prospective study that was undertaken during a 6-month period from April to October 2000, within the Vitreo-retinal Service at the Tennent Institute of Ophthalmology, Gartnavel General Hospital, Glasgow, Scotland, United Kingdom.

Protocol

The testing protocol was very similar to that described in a previous study. Subjects were seated and viewed a computer touchscreen (luminance 57 candels [cd]/m²; IBM, Greenock, UK) from a distance of 40 cm. Their heads were stabilized with chin rests and cheek pads. Pictures of three vertical poles were presented on the screen: in the center and $15^\circ$ to the left and to the right of center (Fig. 1). A red target...
Subjects

Sixty patients who underwent surgery for primary rhegmatogenous retinal detachment participated in the study and were divided into two groups of 30 as follows: group 1: those who underwent primary external scleral-buckling surgery (mean age 48 ± 17 [SD] years; range, 19–83 years); group 2: those who underwent primary vitrectomy (mean age 55 ± 15 years; range, 23–73 years). Their clinical details are summarized in Table 1. The choice of surgical procedure to be performed was decided by one of the vitreoretinal surgeons (HMH, TB, or JM) and was dependent on the requirements of individual patients.

The number of subjects necessary to detect a difference between the two groups with a power of 90% at the 5% significance level was determined using a power calculation. The SD required for this calculation was derived from a pilot study. None of the subjects had any ophthalmic history of note and no medical history that could have affected their ocular motility or pointing responses. Visual acuities were recorded with appropriate refractive correction using the log minimum angle of resolution (MAR) crowded test at a distance of 3 m.

Surgical Procedure

All surgery was performed with patients under general anesthesia. The conventional external scleral-buckling procedures consisted of drainage of subretinal fluid and application of cryotherapy in the region of the retinal break(s), to create an adhesion between the sensory retina and the underlying retinal pigment epithelium. Silicone explants were placed overlaying the retinal break(s) and oriented either circumferentially (n = 25) or radially (n = 5). An encircling band was also used when appropriate (n = 12). Intravitreal gas was used to effect temporary internal tamponade as required. All four of the rectus muscles were sutured to aid movement of the eye. The vitrectomy procedures consisted of a standard three-port pars plana approach, with internal drainage of subretinal fluid, followed by fluid–gas exchange. Externally, cryotherapy was applied in the region of the retinal hole(s). No muscle slings or external buckles were used in the vitrectomy group.

Results

All subjects were able to perform the test without difficulty on each occasion. Normality testing confirmed a gaussian distribution of the data allowing parametric statistical tests to be performed. The macula was detached in 16 patients and attached in 14 in the scleral-buckling group and was detached in 23 patients and attached in 7 in the vitrectomy group. Before surgery, the visual acuity of the surgical eyes ranged from 0.025 log units to hand movements in the scleral-buckling group and from 0.15 log units to perception of light in the vitrectomy group. The mean visual acuity of the fellow nonsurgical eyes was 0.02 ± 0.09 (SD) log units in the scleral-buckling group and 0.04 ± 0.11 log units in the vitrectomy group. The mean visual acuity of the nonsurgical eye did not change in the postoperative period. The mean length of time between the first and second postoperative assessments was 10.3 ± 1.9 (SD) days in the scleral-buckling group and 9.8 ± 2.1 days in the vitrectomy group.

Analysis of variance showed that the pointing responses for individual subjects to each of the three poles were similar during each testing session (F = 0.55, P = 0.74). In view of

Table 1. Clinical Details of the Two Groups of Patients

<table>
<thead>
<tr>
<th></th>
<th>Scleral Buckling</th>
<th>Vitrectomy</th>
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<tbody>
<tr>
<td>Age (y)</td>
<td>48 ± 17</td>
<td>55 ± 15</td>
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<tr>
<td>Refractive error (D)</td>
<td></td>
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<tr>
<td>Surgical eye</td>
<td>−3.40 ± 3.6</td>
<td>−3.30 ± 4.4</td>
</tr>
<tr>
<td>Fellow eye</td>
<td>−3.30 ± 3.5</td>
<td>−3.10 ± 4.2</td>
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<td>Affered eye (n)</td>
<td></td>
<td></td>
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<tr>
<td>Right</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Left</td>
<td>16</td>
<td>13</td>
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Age and refractive error are expressed as means ± SD. Refractive errors represent mean spherical equivalent in diopters.
this, the data were collapsed to obtain a single value of the mean pointing response for each patient for that particular testing session. In the scleral-buckling group there was a significant shift in spatial localization of $2.9 \pm 0.9^\circ$ (SD; 95% confidence interval 2.4-3.2$^\circ$) on the first postoperative day (Fig. 2). This was statistically significant ($P < 0.0001$, $t = 17.9$; one-sample $t$-test). In the vitrectomy group there was also a significant shift in spatial localization of $1.3 \pm 0.6^\circ$; 95% confidence interval 1.1-1.5$^\circ$) on the first postoperative day ($P < 0.0001$, $t = 12.3$; Fig. 2). A comparison of the changes in localization observed in each of these two groups at this time showed that they were significantly different from each other ($P < 0.0001$, $t = 8.55$; unpaired $t$-test). At the subsequent follow-up assessment 10 days later, these changes had returned toward preoperative values in both groups of patients (Fig. 2). For example, there was a small, nonsignificant difference between the preoperative and second postoperative testing sessions of $0.5 \pm 0.7^\circ$ ($P = 0.25$, $t = 1.2$) in the scleral-buckling group and $0.4 \pm 0.6^\circ$ ($P = 0.35$, $t = 0.95$) in the vitrectomy group. There was no significant difference between the changes observed in each group ($P = 0.14$, $t = 1.4$). No correlation was found between the age or refractive errors of the patients and the size of localization shifts.

**DISCUSSION**

This study demonstrates that spatial localization in patients with primary rhegmatogenous retinal detachment alters significantly more after external scleral-buckling procedures compared with vitrectomy procedures, when viewing with the nonsurgical eye. The technique we used is a recognized method for assessing localization. Although a randomized study would have been optimal, it was not feasible, because the decision about the type of surgery to be performed was determined by the clinical status of each patient.

The results from the scleral-buckling group are consistent with those previously reported by Campos et al.,$^{12}$ not only in the size of the localization shifts, but also in the time taken for the observed changes to return to their preoperative values, approximately 10 days later. However, they noted alterations in only 4 of 10 patients when testing the fellow non–surgically treated eye. In contrast, we noted changes in all subjects who underwent scleral-buckling surgery, ranging from 1.3 to 4.6$^\circ$. It is possible that this difference is related to the more sensitive technique we used, in which pointing responses were recorded on a computer touchscreen, rather than the method Campos et al. describe, in which the position of the target was indicated on a piece of paper. The pointing changes we found in this group are of a similar magnitude to those in previous studies in which extraocular muscle proprioception was manipulated experimentally, resulting in mean localization shifts of 2.5$^{16}$ and 2.98$^\circ$. They are also in keeping with the findings of Steinbach and Smith$^8$ who observed changes after strabismus surgery, results that were attributed to modified afferent feedback from the extraocular muscles of the surgically treated eye.

To the best of our knowledge alterations in spatial localization after vitrectomy procedures for retinal detachments have not been reported previously. Why should these changes occur after a procedure that does not appear to involve the extraocular muscles directly? As was discussed in the introduction the viewer relies on a combination of both retinal (visual) and extraretinal information to determine the location of targets with respect to himself or herself. Because all the patients were tested with the surgical eye patched, and because the visual acuity of the nonsurgical eye remained the same after surgery, then an alteration in retinal information is unlikely to account for the results. This indicates that a nonvisual (i.e., extraretinal) signal has influenced spatial localization in the fellow eye. As was outlined earlier, there are two possible sources of this extraretinal information: efference copy and extraocular muscle proprioception.

Could the efferent copy of the oculomotor command change after vitrectomy? This is possible, particularly because ocular motility problems have been reported after this procedure.$^{15}$ However, it should be noted that these changes were recorded several months after surgery, and little is known about ocular motility in the immediate postoperative period. In addition, our testing was performed monocularly, when viewing with the normal fellow eye, and according to Walls,$^9$ the visual system monitors only the efference command sent to the dominant eye. Bridgeman$^4$ also supports the concept that there is only one copy of the efferent command. Because there is no reason to believe that the motility of the nonsurgical eye has changed, we cannot be sure whether efference copy influenced the extraretinal eye position signal under the circumstances of our testing procedure.

The other possible source of the modified extraretinal information is extraocular muscle proprioception. Although no muscle slings or scleral buckles were used during the vitrectomy procedures, a degree of manipulation and rotation of the globe during surgery is inevitable. This may have produced swelling and inflammation in the peribulbar tissues in proximity to the extraocular muscles, which in turn could have caused an alteration in proprioceptive feedback. It is also conceivable that peribulbar, rather than extraocular, muscle receptors may be the source of this modified afferent signal.$^16$ However, there is little direct evidence to support the existence of such receptors used in this study.

Although we cannot discount the role of efference copy after vitrectomy, the balance of evidence suggests that the changes in spatial localization we observed are related to an alteration in a nonvisual feedback signal derived from the surgical eye. The most likely source of such a signal is extraocular muscle sensory receptors.

Although the prime concern in patients who undergo any form of retinal detachment surgery is successful reattachment of the retina with improved visual function, in our experience some patients report difficulty in judging the position of objects relative to themselves. Although this is likely to be related to reduced acuity in the affected eye, combined with postoperative inflammation and mydriasis, our findings suggest that particularly after scleral-buckling procedures, modified ex-
traocular muscle proprioception could be a contributory factor immediately after surgery. What effect these and other surgical procedures involving the extraocular muscles, have on other aspects of visual function, such as oculomotor control, is not known, but perhaps warrants further assessment.

References