Automatic Three-Dimensional Magnetic Resonance-based measurements of tumour prominence and basal diameter for treatment planning of uveal melanoma

Supplementary Materials

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Appendix A: Image acquisition details

The MRI-scans were acquired with a 3T Philips Ingenia MRI-scanner (Philips Healthcare, Best, the Netherlands) with a 4.7 cm surface receive coil (Philips Healthcare), according to an earlier described protocol [15,16]. The 3D T1gd (acquisition voxel size 0.8x0.8x0.8mm$^3$, scan time 02:07 min) and the 3D T2-weighted images (acquisition voxel size 0.8x0.8x0.8mm$^3$, scan time 02:57 min) were used for tumour delineation. The multi-slice and functional scans were used as a reference to differentiate tumour from retinal detachment and to evaluate invasion into surrounding structures.

B-scan ultrasound images were obtained by an ocular oncologist with a 10 MHz transducer or a 50 MHz biomicroscopy (UBM) transducer (Aviso, Quantel Medical, Cournon-d'Uuvergne, France). Prominence measurements were performed perpendicular to the sclera, LBD was found by manually scanning for the direction of the longest axis and SBD was measured perpendicularly to the LBD [25].
Appendix B: Evaluation of 3D prominence and tumour base definitions in uveal melanoma – a pilot study

Introduction
The aim of this pilot study was to determine a 3D prominence and basal diameter definition suitable for brachytherapy and proton beam therapy planning and evaluate these, based on 3D MRI tumour contours.

Methods
In a multidisciplinary tumour board, consisting of ocular oncologists, radiation oncologists, clinical physicists and radiologists, three prominence and three base definitions were devised.

Tumour contours on T1gd-weighted MRI were used to evaluate these prominence (Figure 1) and base (Figure 2) definitions:

- Hausdorff distance: Hausdorff distance between tumour top and base. This determines the largest distance within the tumour, i.e. the largest distance that the beta particles will have to travel in case of ruthenium brachytherapy.
- Sclera-based definition: largest distance between tumour top and base, perpendicular to the sclera. This definition is based on description of B-mode ultrasound measurements as performed by ocular oncologists in the case of an idealized spherical eye.
- Centre-based definition: distance between tumour apex and base, measured along the line between centre of the globe and tumour apex, where tumour apex is defined as the point of the tumour closest to the centre of the globe. This definition is based on the current ocular radiotherapy planning methods, where the tumour apex is used to define the clinical target volume.

The LBD was the largest distance between two points in the tumour base, with the base defined as follows:

- Non-projected: The tumour base defined as the cross-section between tumour and choroid. However, this definition may result in an underestimation of overhanging tumours (Main text figure 1).
- Projected base: Non projected base, extended by the projection of the tumour on the sclera from the centre of the eye. This definition was added to accommodate for a better description of overhanging tumours.
- Parallel projected base: Non projected base, extended by the projection of the tumour on the sclera, parallel to centre-based prominence definition. This definition was added to accommodate for a better description of overhanging tumours and is an alternative to the projected base mentioned before.

Results were evaluated in a multidisciplinary tumour board, consisting of ocular oncologists, radiation oncologists, clinical physicists and radiologists. Assessment criteria were (a) the measurement had to be similar to the clinical ultrasound measurement, e.g. perpendicular to the sclera, and (b) had to be suited to use in both brachytherapy planning and proton beam therapy planning.
Results
For the prominence, differences between all definitions were <0.5 mm for 13/25 patients. For 9/25 patients, the Hausdorff distance and the centre-based definition were similar, but the sclera-based definition resulted in an oblique measurement (Figure 3a). For 3/25 patients, the Hausdorff distance resulted in a measurement on the edge of the tumour (Figure 3b), which was judged to not represent the current ultrasonic prominence measurements. The centre-based definition gave consistent results for all patients, and yielded a visually similar measurement as obtained clinically on ultrasound.

For the LBD, the projected base overestimated the tumour base in non-overhanging tumours (Figure 4a). The parallel projected base offered an adequate description of overhanging tumours and non-overhanging tumours (Figure 4b). The non-projected base gives an adequate description of non-overhanging tumours, but lacks in the representation of overhanging tumours. However, this definition corresponds most to the current ultrasound measurements.

Conclusion
The Hausdorff distance and the sclera-based definition resulted in oblique measurements or measurements at the side of the tumour, whereas the centre-based definition yielded a visually similar measurement as obtained clinically on ultrasound and also matched the desired radiotherapy definition for ocular PBT and brachytherapy. The parallel projected base offered the most adequate description of both non-overhanging and overhanging tumours, however the non-projected base is more comparable to the current measurement methods. Therefore, in this study, for the comparisons between modalities, the non-projected base will be used. For future research, the use of a projected base for measurement of the LBD might be considered.
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Figure 3: (a,c,d) The sclera-based definition gave oblique measurements in 9/25 patients, (b) the Hausdorff distance gave measurements on the side of the tumour in 3/25 patients. In all cases, the centre-based definition gave acceptable results.

Figure 4: (a) The parallel projection of the base (blue) gave an adequate description of both overhanging and non-overhanging tumours, (b) the projection of the base (green) overestimated the base in non-overhanging tumours.
Appendix C: Python code for automatic prominence, LBD and SBD measurements based on .stl files of tumour and vitreous-eye complex

## Automatic 3D tumour measurements for uveal melanoma
# Lisa Klaassen, l.klaassen@lumc.nl, June 2022

# Import packages
import numpy as np
import pandas as pd
import trimesh
from scipy.spatial.distance import pdist, squareform
from scipy.interpolate import griddata
import warnings

# Functions for determination of prominence, LBD and SBD

def Prominence(tumour, eye, sclera_tumour, include_sclera = True):
    # Prominence through centre of the eye and apex of tumour (apex defined by closest point to eye centre)
    Inputs:
     - tumour: trimesh object of tumour
     - eye: trimesh object of vitreous-lens complex
     - sclera_tumour: trimesh object of tumour including sclera
     - include_sclera: boolean, set to True if prominence should be measured including sclera
    Outputs: prominence (prom), top coordinate of prominence (prom_top), base coordinate of prominence (prom_base)
    
    mmp = eye.center_mass
    apex_coor = trimesh.proximity.closest_point(tumour, np.reshape(eye.center_mass, [1,3]))[0]
    # Tumour apex is defined as point of the tumour closest to eye centre
    dist_to_top = trimesh.proximity.closest_point(tumour, np.reshape(eye.center_mass, [1,3]))[1]
    if dist_to_top < 0.4:
        warnings.warn('Warning: distance to top is smaller than 0.4 mm, manually check result')
    # Finding intersection with sclera at tumour base
    origins = np.reshape([mmp], [1,3])
    if not tumour.contains(np.reshape(mmp, [1,3])):
        directions = np.reshape([apex_coor-mmp], [1,3])
    if tumour.contains(np.reshape(mmp, [1,3])):
        directions = np.reshape([mmp-apex_coor], [1,3])
        warnings.warn('Center of mass is inside tumour, manually check result')
    if include_sclera == True:
        intersector_tumour = trimesh.ray.ray_triangle.RayMeshIntersector(sclera_tumour)
        if include_sclera == False:
            intersector_tumour = trimesh.ray.ray_triangle.RayMeshIntersector(tumour)
    intersect_coordinates = intersector_tumour.intersects_id(origins, directions, return_locations=True, multiple_hits=True)
# Calculating prominence
prom_top = apex_coor[0]
prom1 = np.sqrt((intersect_coordinates[2][0][0]-top_coor[0])**2 +
(intersect_coordinates[2][0][1]-top_coor[1])**2 + (intersect_coordinates[2][0][2]-
top_coor[2])**2) #Prominence is distance between top and base coordinate

# These if statements are needed because the multiple hits from intersects_id are not in a
# logical order
if len(intersect_coordinates[2]) > 1:
prom2 = np.sqrt((intersect_coordinates[2][1][0]-top_coor[0])**2 +
(intersect_coordinates[2][1][1]-top_coor[1])**2 + (intersect_coordinates[2][1][2]-
top_coor[2])**2)
if prom2 > prom1:
    prom = prom2
    base_coor = intersect_coordinates[2][1]
else:
    prom = prom1
    base_coor = intersect_coordinates[2][0]
else:
    prom = prom
prom_base = intersect_coordinates[2][0]
return prom, prom_base, prom_top

def LBD(tumour, eye):
    """
    Calculation of largest basal diameter
    Inputs: trimesh object of tumour and eye
    Outputs: LBD, two coordinates of LBD (lbd_coor1, lbd_coor2)
    """
    base = trimesh.boolean.difference([tumour, eye], 'scad')
    base.export('path') #insert own path
    lbd_dist = squareform(pdist(base.vertices, 'euclidean'))
lbd = np.max(lbd_dist)
idx_lbd = np.unravel_index(lbd_dist.argmax(), lbd_dist.shape)
lbd_coor1 = base.vertices[idx_lbd[0]]
lbd_coor2 = base.vertices[idx_lbd[1]]
return lbd, lbd_coor1, lbd_coor2

def SBD(tumour, base, lbd_coor1, lbd_coor2, prom_base, prom_top):
    """
    Function to determine second basal diameter. Projects tumour base onto 2D grid and
    Inputs: LBD coordinates, prominence coordinates, base (trimesh object), tumour (trimesh
    object) """
    points_base = base.vertices
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```python
# Translate all inputs to have prominence base coordinate at (0,0,0) and rotate all inputs to have prominence along z-axis
vec_z = [0,0,np.linalg.norm(prom_top-prom_base)]
vec_prom = prom_top-prom_base

rot_mat = rotation_matrix_from_vectors(vec_prom,vec_z) #Aligns vec_prom with vec_z
rot_mat2 = rotation_matrix_from_vectors(vec_z,vec_prom)

transl = np.reshape(-prom_base, [3,1])
points_base = points_base + np.repeat(np.reshape(transl,[1,3]), len(points_base), axis =0)

rot_mat2 = np.array([[np.cos(angle1), -np.sin(angle1),0], [np.sin(angle1), np.cos(angle1),0], [0,0,1]])
rot_mat_3D_2 = np.array([[np.cos(angle1), -np.sin(angle1),0], [np.sin(angle1), np.cos(angle1),0], [0,0,1]])

# Make a grid and interpolate tumour contour onto grid
lbd_2D = np.linalg.norm(lbd_coor1_2D-lbd_coor2_2D)
gridx, gridy = np.mgrid[-1.2*lbd_2D:1.2*lbd_2D:0.01, -1.2*lbd_2D:1.2*lbd_2D:0.01] #Grid has a resolution of 0.01 mm
```
grid_z = griddata(base_3D[:,0:2], base_3D[:,2], (gridx, gridy), method = 'cubic', fill_value = 'nan')

# Check y-axis for least NaNs (as this direction contains the longest perpendicular diameter)
non_nans = (~np.isnan(grid_z)).sum(1)
idx_x = np.argmax(non_nans)

#Find index of last and first and last non-NaN for this column
col = pd.Series(grid_z[idx_x, :], index = list(range(len(grid_z))))
idx_y1 = col.first_valid_index()
idx_y2 = col.last_valid_index()

sbd_2D = np.linalg.norm(np.array([gridx[idx_x,idx_y1], gridy[idx_x,idx_y1]]) - np.array([gridx[idx_x,idx_y2], gridy[idx_x,idx_y2]]))
sbd_c1 = np.array([gridx[idx_x,idx_y1], gridy[idx_x,idx_y1], grid_z[idx_x,idx_y1]])
sbd_c2 = np.array([gridx[idx_x,idx_y2], gridy[idx_x,idx_y2], grid_z[idx_x,idx_y2]])

# Back to three dimensions
# Translate and transform SBD points back to original coordinate system
sbd_c1_back = np.reshape(np.dot(sbd_c1, rot_mat_3D_2), [3,1])
sbd_c2_back = np.reshape((np.dot(sbd_c2, rot_mat_3D_2)), [3,1])
sbd_c1_back[0] = sbd_c1_back[0] + x_intersect
sbd_c2_back[0] = sbd_c2_back[0] + x_intersect

sbd_c1_orig = np.dot(rot_mat2, sbd_c1_back) - np.reshape(transl, [3,1])
sbd_c2_orig = np.dot(rot_mat2,sbd_c2_back) - np.reshape(transl, [3,1])

#Find closest tumour points from suggested SBD
sbd_coor1 = trimesh.proximity.closest_point(tumour, np.reshape(sbd_c1_orig, [1,3]))[0]
sbd_coor2 = trimesh.proximity.closest_point(tumour, np.reshape(sbd_c2_orig, [1,3]))[0]

sbd = np.linalg.norm(sbd_coor1 - sbd_coor2)
return sbd, sbd_coor1, sbd_coor2

def rotation_matrix_from_vectors(vec1, vec2):
    """ Find a rotation matrix that aligns vec1 to vec2
    Inputs: vec1: A 3d "source" vector, vec2: A 3d "destination" vector
    Returns: rotation_matrix (A transform matrix (3x3) which when applied to vec1, aligns it with vec2)
    Adapted from https://stackoverflow.com/questions/63525482/finding-the-rotation-matrix-between-two-vectors-in-python"
    a, b = (vec1 / np.linalg.norm(vec1)).reshape(3), (vec2 / np.linalg.norm(vec2)).reshape(3)
    v = np.cross(a, b)
    c = np.dot(a, b)
    s = np.linalg.norm(v)
    kmat = np.array([[0, -v[2], v[1]], [v[2], 0, -v[0]], [-v[1], v[0], 0]])
    rotation_matrix = np.eye(3) + kmat + kmat.dot(kmat) * ((1 - c) / (s ** 2))
    return rotation_matrix

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### Appendix D: Overview of prominence, LBD and SBD for all patients and measurement methods

| Patient | Tumour location | AICC classification | Treatment | US [mm] | MRI manual T2 [mm] | MRI auto T2 [mm] | MRI auto T1gld [mm] | MRI manual T1gld [mm] | Angle between manual & automatic [deg] | Remarks | US [mm] | MRI auto T1gld [mm] | Remarks | T1gld [mm²] | T2 [mm²] |
|---------|----------------|---------------------|-----------|---------|-------------------|----------------|-------------------|-------------------|--------------------------|---------|---------|------------------|---------|-------------|---------|
| Pt001   | Posterior      | T4                  | PRT       | 3.1     | No clinical prominence measurement due to flatness | 2.5            | 2.5               | 18.1             | 17.3                     | 18.0              | 18.5 | 31 | MRI extent difficult to assess due to flatness | 17.1 | 13.0 | 294 | 205 |
| Pt002   | Anterior       | T3                  | PRT       | 8.4     | 9.3               | 8.7            | 9.3               | 15.6             | 16.8                     | 16.5              | 17.2 | 2 | US: top not in FOV | 13.6 | 14.0 | 841 | 699 |
| Pt003   | Anterior       | T3                  | PRT       | 9.1     | 11.4              | 10.4           | 10.7              | 14.8             | 15.7                     | 15.4              | 15.6 | 3 | US: entire base not in FOV | 13.7 | 14.3 | 898 | 827 |
| Pt004   | Posterior      | T3                  | PRT       | 9.0     | 9.5               | 9.7            | 9.3               | 15.1             | 16.1                     | 14.3              | 16.0 | 2 | US: entire base not in FOV | 12.7 | 13.8 | 816 | 770 |
| Pt005   | Posterior      | T1                  | PRT       | 3.4     | 3.6               | 3.0            | 3.7               | 7.5              | 9.4                      | 7.0              | 9.3  | 8 | US: entire base not in FOV | 6.7  | 8.9  | 838 | 49  |
| Pt006   | Anterior       | T4                  | PRT       | 10.5    | 10.7              | 11.1           | 10.8              | 16.6             | 20.7                     | 21.0              | 21.1 | 10 | US: entire base not in FOV | 15.5 | 15.4 | 1899 | 1431 |
| Pt007   | Posterior      | T2                  | PRT       | 2.5     | 2.4               | 2.7            | 3.0               | 15.2             | 17.5                     | 19.1              | 22.8 | 63 | MRI extent difficult to assess | 14.9 | 20.1 | 423 | 194 |
| Pt008   | Posterior      | T2                  | PRT       | 8.0     | 8.1               | 8.6            | 7.7               | 11.7             | 14.0                     | 10.6              | 13.6 | 3 | MRI extent difficult to assess | 8.0  | 10.6 | 280 | 306 |
| Pt009   | Posterior      | T3                  | PRT       | 8.9     | 8.4               | 8.3            | 8.4               | 15.0             | 15.3                     | 16.3              | 16.9 | 83 | US: entire base not in FOV | 14.8 | 15.0 | 747 | 720 |
| Pt010   | Anterior       | T3                  | PRT       | 7.8     | 7.7               | 7.7            | 7.5               | 16.5             | 16.6                     | 16.6              | 17.6 | 59 | US: entire base not in FOV | 16.2 | 16.5 | 863 | 617 |
| Pt011   | Posterior      | T3                  | PRT       | 9.3     | 10.2              | 9.9            | 9.4               | 14.2             | 10.5                     | 14.0              | 13.1 | 28 | US: entire base not in FOV | 8.3  | 9.0  | 440 | 486 |
| Pt012   | Anterior       | T3                  | PRT       | 13.3    | 13.0              | 12.0           | 12.4              | 12.8             | 15.5                     | 14.4              | 16.0 | 23 | US: entire base not in FOV | 10.2 | 14.9 | 1097 | 976 |
| Pt013   | Anterior       | T3                  | PRT       | 8.3     | 8.4               | 7.5            | 8.1               | 16.2             | 15.3                     | 13.6              | 16.3 | 41 | US: entire base not in FOV | 14.7 | 15.2 | 726 | 506 |
| Pt014   | Posterior      | T3                  | PRT       | 9.2     | 9.5               | 9.7            | 9.6               | 16.9             | 15.6                     | 16.2              | 16.0 | 23 | US: entire base not in FOV | 14.1 | 13.8 | 769 | 822 |
| Pt015   | Posterior      | T2                  | PRT       | 5.1     | 4.6               | 4.5            | 4.8               | 11.4             | 12.2                     | 7.8              | 12.4 | 1 | US: haemorrhage included in tumour measurement | 9.6  | 7.8  | 75  | 85  |
| Pt016   | Posterior      | T2                  | PRT       | 6.4     | 6.9               | 6.4            | 6.1               | 6.4              | 7.5                      | 6.2              | 8.0  | 36 | MRI extent difficult to assess | 5.8  | 7.7  | 163 | 112 |
| Pt017   | Posterior      | T1                  | PRT       | 3.4     | 2.7               | 2.7            | 2.7               | 7.4              | 8.3                      | 6.0              | 8.2  | 60 | MRI extent difficult to assess | 4.7  | 7.7  | 67  | 30  |
| Pt018   | Posterior      | T2                  | Ru-106    | 6.0     | 6.9               | 6.1            | 6.2               | 16.6             | 15.0                     | 13.3              | 15.6 | 51 | MRI extent difficult to assess | 13.4 | 15.4 | 445 | 308 |
| Pt019   | Posterior      | T2                  | Ru-106    | 5.3     | 4.1               | 5.1            | 5.0               | 17.0             | 16.2                     | 10.2              | 16.9 | 5 | MRI extent difficult to assess | 11.3 | 13.3 | 278 | 154 |
| Pt020   | Posterior      | T1                  | Ru-106    | 5.6     | 5.1               | 5.5            | 5.6               | 9.0              | 11.7                     | 9.9              | 12.9 | 22 | US: entire base not in FOV | 8.1  | 9.6  | 223 | 171 |
| Pt021   | Anterior       | T2                  | Ru-106    | 5.5     | 5.7               | 5.6            | 5.9               | 12.4             | 13.0                     | 10.3              | 14.4 | 41 | US: entire base not in FOV | 11.3 | 11.2 | 279 | 213 |
| Pt022   | Posterior      | T2                  | Ru-106    | 5.1     | 5.4               | 5.2            | 5.3               | 15.0             | 16.9                     | 15.9              | 16.5 | 3 | US: entire base not in FOV | 12.0 | 11.4 | 372 | 287 |
| Pt023   | Posterior      | T2                  | Ru-106    | 4.0     | 3.4               | 4.1            | 4.8               | 10.0             | 10.3                     | 12.3              | 10.6 | 46 | US: entire base not in FOV | 8.0  | 10.2 | 130 | 142 |
| Pt024   | Posterior      | T2                  | Ru-106    | 5.5     | 5.3               | 5.4            | 5.4               | 12.2             | 14.9                     | 14.2              | 15.0 | 1 | US: entire base not in FOV | 12.1 | 12.2 | 284 | 270 |

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Supplementary Table 1: Overview of all comparisons performed.

|                  | US - MRI manual | US - T1gd automatic | US - T2 automatic | MRI manual - T1gd automatic | MRI manual - T2 automatic | T2 automatic - T1gd automatic |
|------------------|-----------------|---------------------|-------------------|-----------------------------|---------------------------|-----------------------------|
| **Prominence**   |                 |                     |                   |                             |                           |                             |
| Median           |                 |                     |                   |                             |                           |                             |
| (max) absolute   |                 |                     |                   |                             |                           |                             |
| difference [mm]  |                 |                     |                   |                             |                           |                             |
| **Entire group** | 0.4 (2.3)       | 0.3 (1.6)           | 0.4 (1.3)         | 0.3 (0.9)                   | 0.4 (1.1)                 | 0.3 (0.9)                   |
| Anterior location| 0.2 (2.3)       | 0.4 (1.6)           | 0.6 (1.3)         | 0.2 (0.7)                   | 0.6 (1.0)                 | 0.3 (0.6)                   |
| Posterior location| 0.5 (1.2)     | 0.3 (1.3)           | 0.4 (0.7)         | 0.3 (0.9)                   | 0.3 (1.1)                 | 0.3 (0.9)                   |
| **LBD**          |                 |                     |                   |                             |                           |                             |
| Median           |                 |                     |                   |                             |                           |                             |
| (max) absolute   |                 |                     |                   |                             |                           |                             |
| difference [mm]  |                 |                     |                   |                             |                           |                             |
| **Entire group** | 1.0 (4.1)       | 1.1 (7.6)           | 1.1 (6.8)         | 0.5 (5.3)                   | 1.6 (6.0)                 | 1.7 (6.7)                   |
| Anterior location| 0.9 (4.1)       | 1.6 (4.5)           | 1.6 (4.4)         | 0.5 (1.4)                   | 0.3 (2.7)                 | 1.0 (4.1)                   |
| Posterior location| 1.1 (3.7)     | 1.0 (7.6)           | 1.1 (6.8)         | 0.5 (5.3)                   | 1.8 (6.0)                 | 1.8 (6.7)                   |
| **SBD**          |                 |                     |                   |                             |                           |                             |
| Median           |                 |                     |                   |                             |                           |                             |
| (max) absolute   |                 |                     |                   |                             |                           |                             |
| difference [mm]  |                 |                     |                   |                             |                           |                             |
| **Entire group** | N.A.            | 1.1 (5.2)           | N.A.              | N.A.                        | N.A.                      | N.A.                        |
| Anterior location| N.A.            | 0.4 (4.7)           | N.A.              | N.A.                        | N.A.                      | N.A.                        |
| Posterior location| N.A.          | 1.8 (5.2)           | N.A.              | N.A.                        | N.A.                      | N.A.                        |
| **Volume**       |                 |                     |                   |                             |                           |                             |
| Median           |                 |                     |                   |                             |                           |                             |
| (max) absolute   |                 |                     |                   |                             |                           |                             |
| difference [mm³] |                 |                     |                   |                             |                           |                             |
| **Entire group** | N.A.            | N.A.                | N.A.              | N.A.                        | N.A.                      | 66 (789)                    |

Supplementary Figure 1: Overview of prominence definitions

Supplementary Figure 1: (a,c,d) The sclera-based definition gave oblique measurements in 9/25 patients, (b) the Hausdorff distance gave measurements on the side of the tumour in 3/25 patients. In all cases, the centre-based definition gave acceptable results.

Supplementary Materials for "Automatic Three-Dimensional Magnetic Resonance-based measurements of tumour prominence and basal diameter for treatment planning of uveal melanoma"
Supplementary Figure 2: Tumours marked separately

Supplementary Figure 2: Tumours with incomplete visualization of the tumour extent were marked separately. On ultrasound, this was due to either (a) limited penetration depth or (b) limited field of view of the ultrasound transducer. In some flat UM the extent of flat tumour components was difficult to assess on MRI (c,d). (d): the area that was thickened and enhanced compared to the native T1-weighted scan was considered tumour.

Supplementary Figure 3: Angle between automatic and manual LBD measurement

Supplementary Figure 3: Relationship between angle between automatic and manual LBD measurement and difference between the two methods.
Supplementary Figure 4: Haemorrhage on top of tumour results in prominence overestimation on ultrasound

Supplementary Figure 4: After retrospective re-evaluation of the ultrasound image and corresponding fundus photographs of the patient with a 1.3 mm difference between ultrasound and T1gd, it was concluded that haemorrhage at the tumour apex was erroneously included in the ultrasound prominence measurement.

Supplementary Figure 5: SBD on ultrasound and MRI

Supplementary Figure 5: Comparison of SBD between ultrasound-T1gd and T2-T1gd. T1gd measurements were larger than both T2 and ultrasound measurements.
Supplementary Figure 6: Ultrasound – T2 MRI comparison

Supplementary Figure 6: Ultrasound-T2 comparison for prominence and LBD.

Supplementary Figure 7: Results of shift of globe’s center of mass

Supplementary Figure 7: Robustness of the proposed prominence measurement was assessed by shifting the centre of mass of the globe 0.8 mm (one acquisition voxel) in the anterior and in the posterior direction. The globe was defined as the vitreous, lens and tumour. The resulting prominence measurements were compared to the native T1gd prominence. This analysis yielded a median absolute difference of 0.03 mm, indicating that the influence of the exact location of the globe centre is limited.