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ARTICLE

Geometry and design of a rhomboid flap

Weiguang Ho[a] and Christopher David Jones[b]

[a]Department of Plastic Surgery, Norfolk and Norwich University Hospital, Norwich, UK; [b]Department of Plastic Surgery, Aberdeen Royal Infirmary, Aberdeen, UK

ABSTRACT
The rhomboid flap is a versatile random-pattern transposition flap with many clinical applications and has been adapted in many variations. The rhombic area of excision is associated with an area of "waste", while adapting Quaba's "square peg into a round hole" design is associated with the "pin-cushioning" effect. Using trigonometric calculations, we outline the association between different rhombic areas of excision and "waste", and a method to design a classical Limberg rhomboid flap.

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KEYWORDS
Local flap; rhomboid flap; Limberg flap

Introduction

The rhomboid flap is a versatile random-pattern transposition flap that can be used to reconstruct defects on various anatomical regions. It was first designed by Professor A.A. Limberg of Leningrad who first published on the subject in 1928 [1]. He first outlined his rhomboid flap in English basically as a parallelogram with two angles of 120° and 60°, respectively, with all sides of equal length.

Modern modifications to the rhomboid flap have been described by Quaba in 1987 in a "square peg into a round hole" design [2]. The main disadvantage of this design is the higher rates to pin cushioning due to contracture of the circular defect. The Dufourmental flap is similar to the rhomboid except there is a less acute angle of transposition.

Compound local flaps adopting or incorporating principles from the rhomboid flap include the square flap [3], Orticochea O-Z flap [4,5]. In addition, multiple rhomboid flaps can be utilised in large defects such as the sacral area in pilonidal sinus disease and myelomeningocoeles [6].

The use of the rhomboid flap has also become a mainstay in reconstruction of full-thickness skin defects in the face and remains an indispensable weapon in a plastic surgeon's armamentarium of reconstructive techniques.

Advantages to using a rhomboid flap include:

1. Superior colour and texture match due to compliance with Gillies' principles of replacing "like for like".
2. Simple to design.
3. Minimal donor site morbidity.
4. Reliable blood supply and sensate.

Skin cancer surgery and reconstruction forms a significant proportion of plastic surgery workload in the UK. Options for reconstruction of large defects that cannot be closed primarily include skin grafts or local flaps. One of the reasons why local flaps are not used is because of the concern that donor sites cannot be closed primarily. In view of this, we sought to explore the geometry of the rhomboid flap, determine how to minimise excision of normal skin and outline steps to design a classical Limberg rhomboid flap.

Geometry

A rhombus is a four-sided shape that has the following properties:

1. All sides are of equal length.
2. Quadrilateral.
3. Opposing angles are equal.
4. All angles are not right angles.

The area (A) of a rhombus is determined by the length of its base (b) multiplied by its height (h) (Figure 1):

$$Area = Base \times height$$

The height in relation to the angle is determined from the following equation:

$$\sin\theta = \frac{h}{b}$$
$$h = b\sin\theta$$

Therefore, area of rhombus (A_R) is calculated as follows:

$$A_R = b \times b\sin\theta = b^2\sin\theta$$

Since θ does not exceed 90° (without producing a shape that is reflectable or rotatable to a shape with similar properties of $\theta < 90°$), the value of A becomes larger as θ increases.

To compare total area excised for a rhomboid flap (between a rhombus and a square) for an excision circle of fixed radius, we have to calculate the length of the base, b.

All sides of the rhombus are the same length, therefore (Figure 2):

$$\sin\theta = \frac{r}{a+r}$$

$$a = \frac{r}{\sin\theta} - r$$

CONTACT Weiguang Ho ho.weiguang@gmail.com Department of Plastic Surgery, Norfolk and Norwich University Hospital, Colney Lane, Norwich NR4 7UY, UK

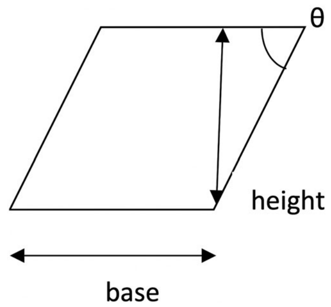

Figure 1. Height and base of a rhombus.

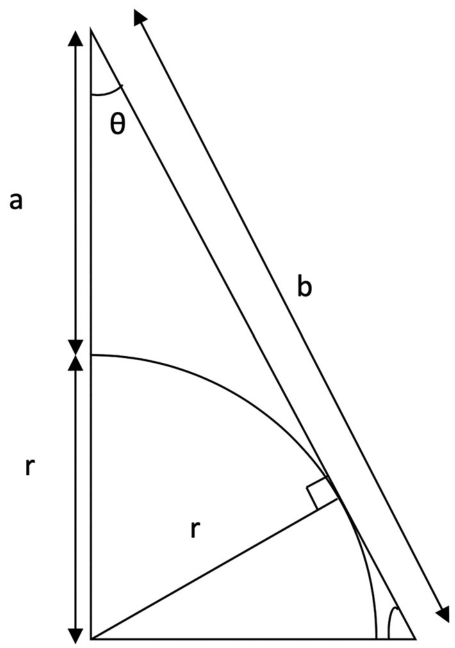

Figure 2. A right-angled triangle representing a quadrisection of a rhomboid, with its hypotenuse (b) representing the base.

Similarly,

$$\cos\theta = \frac{a+r}{b} = \frac{\left(\frac{r}{\sin\theta} - r\right) + r}{b} = \frac{r}{b\sin\theta}$$

$$b = \frac{r}{\sin\theta\cos\theta}$$

When $\theta = 45$ (in a square),

$$b = \frac{r}{\sin 45^\circ \cos 45^\circ} = 2r$$

When $\theta = 30$,

$$b = \frac{r}{\sin 30^\circ \cos 30^\circ} = 2.31r$$

When $\theta = 15$,

$$b = \frac{r}{\sin 15^\circ \cos 15^\circ} = 4r$$

We can observe that when r is constant, as θ decreases, b increases.

Therefore, for a resection circle of the same area, the more acute the angle of the rhombus, the larger the total area excised.

The implication of this is that the ideal quadrilateral shape to ensure minimal excision of normal tissue is where $\theta = 90^\circ$ (i.e. a square).

Maximum area of a circle (A_C) in a rhombus

As mentioned above (where b is the length of a side of the rhombus)

$$b = \frac{r}{\sin\theta\cos\theta}$$

$$r = b\ \sin\theta\cos\theta$$

$$A_C = \pi r^2 = \pi b^2\ \sin^2\theta\cos^2\theta$$

Calculating "waste"

"Waste" is defined as area of excess skin excised that is not part of the tumour excision or clearance margins (A_W).

$$A_W = A_R - A_C$$

$$A_W = b^2\sin\theta - \pi b^2\ \sin^2\theta\cos^2\theta = b^2(\sin\theta - \pi\sin^2\theta\cos^2\theta)$$

Relationship between $\sin\boldsymbol{\theta}$ and A_R

$$A_R = b^2\sin\theta$$

A_R has a linear relationship with sin θ as a function of b^2 (Figure 3).

Relationship between A_c and $\sin^2\boldsymbol{\theta}$

$$A_C = \pi b^2\ \sin^2\theta\cos^2\theta$$

A_C has a linear relationship with $\sin^2\theta$ (Figure 4).

Relationship between "waste" and angle of rhombus

$$A_W = b^2\sin\theta - \pi b^2\ \sin^2\theta\cos^2\theta = b^2(\sin\theta - \pi\sin^2\theta\cos^2\theta)$$

An interesting curve develops that suggests minimal waste in a 90° rhombus (i.e. square) (Figure 5).

Note that for a circular excision "rationalised" to a square, the waste excision is the constant 21.46%, but rationalised to a 60° ellipse, the waste excision rises to 32.5% (Figure 6).

Figure 7 shows a comparative illustration of this concept in practice. In this series of figures, note the increasing area of "waste" as the angle of rhombus increases. Additionally, the area of flap relative to defect and degree of transposition to allow the flap to fall into the defect when the angle is too small or great makes the designs of the left and right rhomboids less than ideal for purpose.

Flap properties of a 60°/120° (classical limberg) rhomboid flap

In order for the flap to adequate cover the defect without excessive tension, area of quadrilateral ABCF has to be equals to area of quadrilateral CDEF (Figure 8). Given that the lengths of all sides of both quadrilaterals are equal, $\theta = \alpha$.

Additionally, as line EF is an extension of imaginary line BF, it forms a bisector of angles ABC and AFC. Therefore,

$$\alpha = \frac{360^\circ - \theta}{2} \text{ or } \alpha = 180^\circ - \frac{\theta}{2}$$

Therefore, the ideal angles θ and α can be solved as below:

$$\alpha = \frac{360^\circ - \alpha}{2}$$

$$3\alpha = 360^\circ$$

$$\alpha = 120^\circ$$

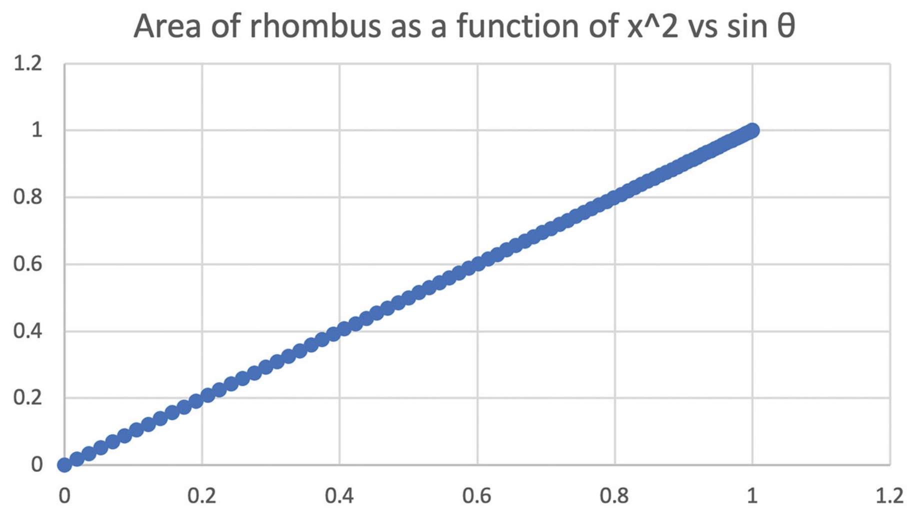

Figure 3. Area of a rhombus as a function of x^2 and sin θ.

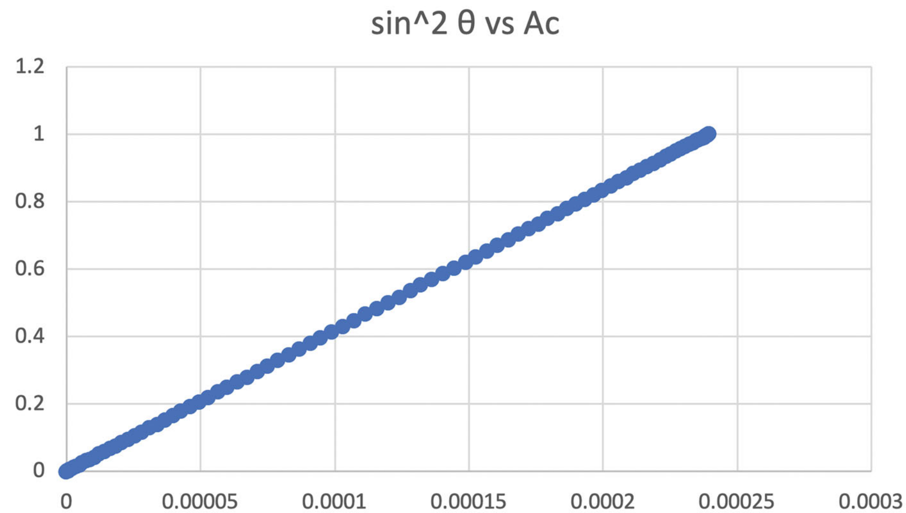

Figure 4. Relationship of $\sin^2 \theta$ and A_c.

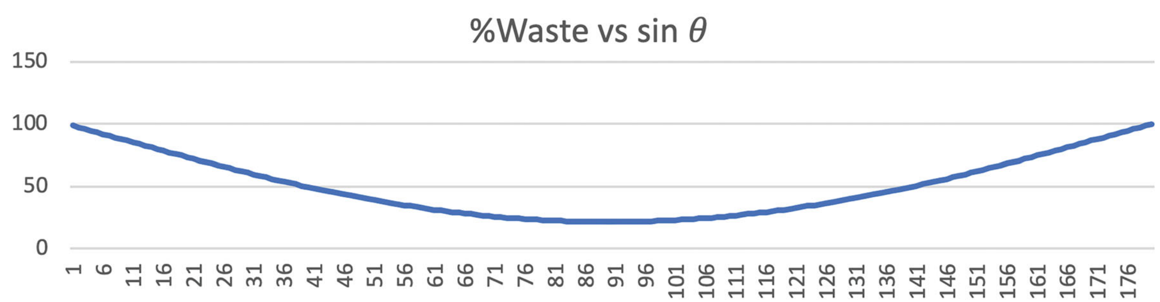

Figure 5. Relationship between percentage waste and sin θ.

Trigonometric properties of the excision rhombus

Let lesion radius be x.

Let excision margins be y.

Let $x + y = z = 1$ (i.e. tumour + excision margins radius = 1) (Figure 9).

As previously discussed, two adjacent angles are 60° and 120°, respectively (Figure 10).

Breaking down the rhomboid into a right-angled triangle, we obtain this configuration (Figure 11). Here, let the length of the long limb of the triangle be $z + a$ (Figure 12).

Dividing the triangle further by drawing a line perpendicular to the hypotenuse and intersecting the centre of the circle (length of this line is equivalent to the radius of the circle, therefore = z) (Figure 13).

Based on the measurements we have, we find that

$$\sin 30^\circ = \left(\frac{z}{a+z}\right)$$

$$a = \left(\frac{z}{\sin 30^\circ}\right) - z$$

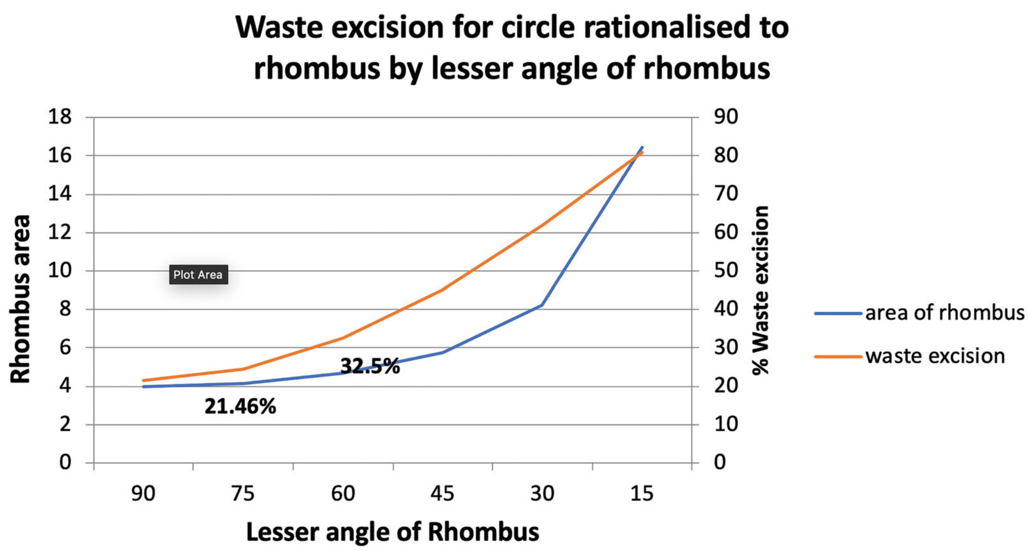

Figure 6. Waste excision of a circle rationalised to rhombus by lesser angle of rhombus.

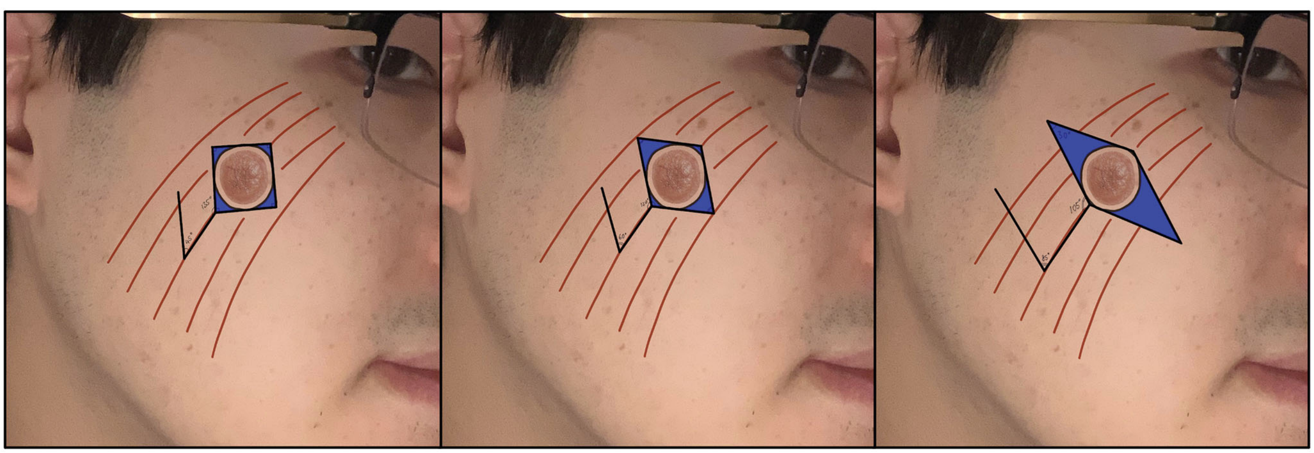

Figure 7. Comparative illustration of rhomboid flap designs with various angles (left, 90° rhomboid or square; centre, 120°–60° rhomboid; right, 150°–30° rhomboid). The blue shaded area represents area of "waste" excision. Note the increasing amount of "waste" area with increasing rhomboid angles consistent with the above calculations.

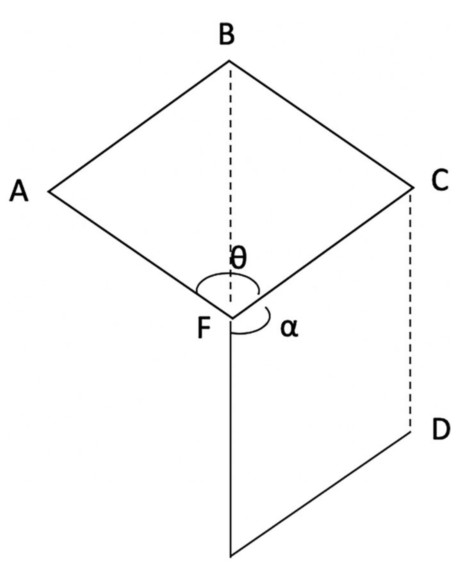

Figure 8. Diagramatic representation of a rhomboid flap, illustrating that area of defect (rhombus ABCF) must be equivalent to area of flap (rhombus DCEF).

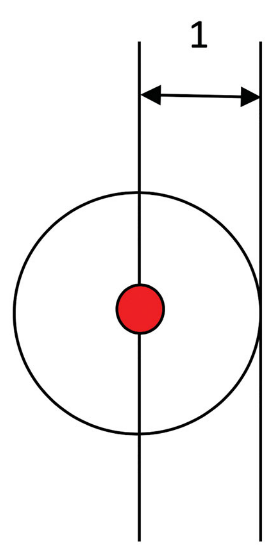

Figure 9. Diagramatic representation of marked area for excision with a radius of one unit length. Red circle = lesion; black circle = excision margins.

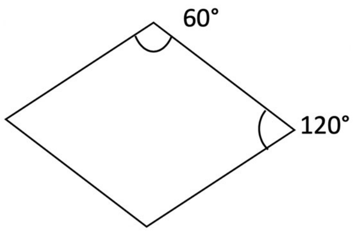

Figure 10. A rhombus with adjacent angles of 60° and 120°.

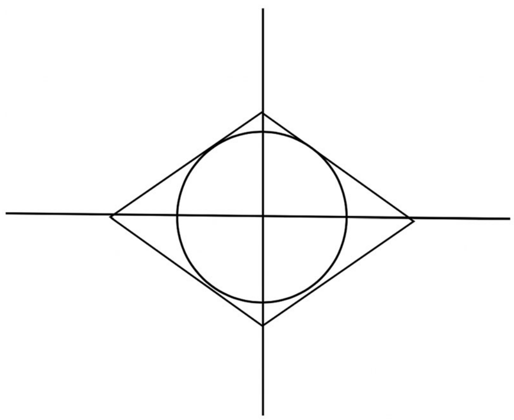

Figure 11. A rhombus with perpendicular lines quadrisecting it. Black circle = excision margins.

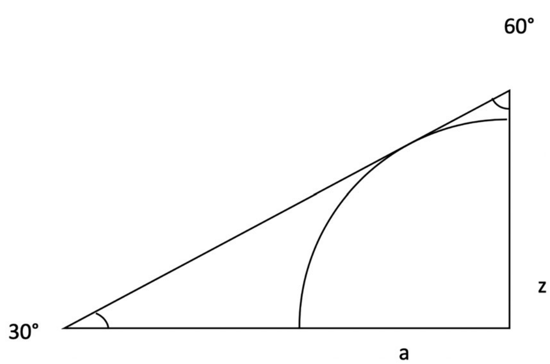

Figure 12. A right-angled triangle representing the quadrisected rhombus in Figure 11.

Let $x + y = z = 1$ (i.e. tumour + excision margins radius =1),

$$a = \left(\frac{1}{\sin 30^\circ}\right) - 1 = 1$$

Technique

In designing a rhomboid flap, the margins of the primary excision or debridement is first marked out and measured. This usually results in a circular or ovoid defect. The aim should generally be to reconstruct the wound and close the secondary defect without compromising functional or aesthetic outcome of the secondary defect or causing a significant "dog ear" deformity. To optimise scaring, the proximal limb the of the flap is marked parallel to resting skin tension lines.

A "pinch test" is then performed to establish whether a sufficient amount of adjacent tissue is available for transposition. This is done by squeezing the distal-most point of the arm of the flap to the proximal-most point together between the operator's thumb and middle finger. They should easily meet to allow closure of the secondary defect without excessive tension.

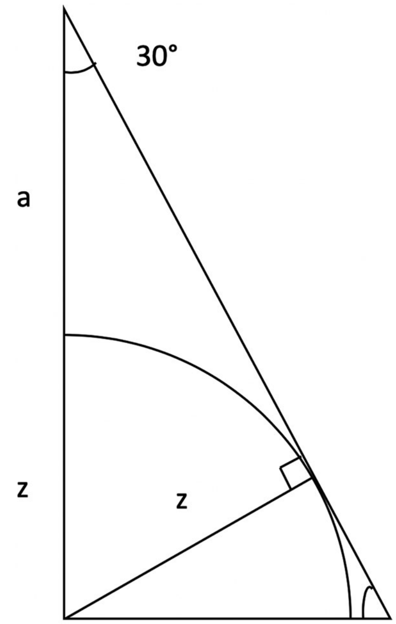

Figure 13. The right-angled triangle in Figure 12 divided with a line perpendicular to its hypotenuse and intersection the centre of the circle.

Full-thickness skin incisions and undermining of the flap are performed along the marked lines with thickness of flap and adjusted to match the thickness of the defect. The flap is then transposed over the defect and all wounds primarily closed. It is crucial to preserve the dermis and some subcutaneous fat in this flap to ensure perfusion of the flap through the subdermal plexus and adequate undermining to allow wound closure with minimal tension. The authors preferred method is a single-layered closure with simple interrupted Ethilon (Johnson & Johnson, Belgium) sutures with suture thickness adjusted according to anatomical location. If required, deep dermal sutures are performed using Monocryl (Johnson & Johnson, Belgium).

Although the 90° angle of a square defect produces the least "waste", the angle of transposition would be greater than a 60° rhomboid defect and the shape of the flap does not match the defect well. In spite of the data above, we would recommend using a rhomboid flap with close compliance to the 60°–120° configuration.

Conclusion

The rhomboid flap is a simple and useful tool to be considered in reconstructing full-thickness skin defects in areas with sufficient skin laxity. We described our approach to its design and execution, and elucidated the geometric principles upon which the technique is based. The learning points from the geometric calculations above include:

1. The larger the angle of the rhomboid, the less "waste" is produced.
2. A classical Limberg rhomboid flap using the described method above based on trigonometric calculations.

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Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Weiguang Ho http://orcid.org/0000-0002-9476-9069

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