Metastatic disease from uveal melanoma: treatment options and future prospects

Richard D Carvajal,1 Gary K Schwartz,1 Tongalp Tezel,2 Brian Marr,3 Jasmine H Francis,3 Paul D Nathan4

ABSTRACT

Uveal melanoma represents ∼85% of all ocular melanomas and up to 50% of patients develop metastatic disease. Metastases are most frequently localised to the liver and, as few patients are candidates for potentially curative surgery, this is associated with a poor prognosis. There is currently little published evidence for the optimal management and treatment of metastatic uveal melanoma and the lack of effective therapies in this setting has led to the widespread use of systemic treatments for patients with cutaneous melanoma. Uveal and cutaneous melanomas are intrinsically different diseases and so dedicated management strategies and therapies for uveal melanoma are much needed. This review explores the biology of uveal melanoma and how this relates to ongoing trials of targeted therapies in the metastatic disease setting. In addition, we consider the options to optimise patient management and care.

INTRODUCTION

Biology of uveal melanoma

Uveal melanoma is the most common primary intraocular malignancy in adults, representing ∼85% of ocular melanomas.1 Remaining ocular melanomas arise from the conjunctiva (∼5%) or other sites (∼10%).1 Uveal melanoma is considered a rare cancer, representing ∼3%–5% of recorded melanoma cases in the USA.1 2 Unlike cutaneous melanoma, the most common subtype, which arises from melanocytes located in the basal layer of the epidermis,3 uveal melanoma arises from melanocytes located anywhere in the uveal tract. Approximately 85%–90% of cases involve the choroid, while those remaining are localised to the iris or ciliary body.4 5 Cutaneous and uveal melanomas are biologically distinct (figure 1) and differ in terms of incidence by gender, race and geographical area.6

Incidence

By contrast to rates of cutaneous melanoma, which have been steadily increasing since the 1970s,6 the incidence of uveal melanoma has remained stable for many years.2 7 In the USA, the mean age-adjusted incidence is 5.1 per million,2 while incidence in Europe varies with latitude being greater in Northern (28 cases per million in Norway and Denmark) compared with Southern (two cases per million in Spain and Italy) Europe.7 Risk factors for the development of uveal melanoma include Caucasian ethnicity, welding, light eye colour (green or blue), dysplastic naevus syndrome, ocular melanocytosis and presence of germline BRCA1-associated protein 1 (BAP1) mutations.8–11

Epidemiology/tumour biology

The molecular profile of uveal melanoma is different from those of cutaneous or mucosal melanomas and is composed of a number of chromosomal abnormalities and somatic gene alterations (figure 1).

Monosomy 3, 1p loss, 1q gain, 6q loss, 6p gain, 8p loss and 8q gain are common chromosomal abnormalities in uveal melanoma.14 15 Ten-year disease-specific mortality rate varies with abnormality.14 15 Monosomy 3 is observed in ∼50% of tumours and is associated with metastatic disease.16 Simultaneous monosomy 3 and chromosome 8 alterations are associated with a worse prognosis, while the outcome is more promising in patients with tumours harbouring partial monosomy 3.16 17

Oncogenic mutations in genes associated with the G-protein-α subunits GNAQ or GNA11 are observed in ≥80% of primary uveal melanomas and are associated with constitutive activation of signalling pathways including the central oncogenic RAS/RAF/MEK/ERK (RAS-ERK) pathway,18–20 thereby driving cell proliferation, tumour growth and progression.21 22 (figure 1).

Inactivating BAP1 mutations are found in ∼50% of all cases, most frequently in class 2 metastasising disease.13 23 BAP1 encodes the catalytic subunit of a nuclear ubiquitin carboxy-terminal hydrolase, with various substrates including BRCA1 and histone H2A.24 25 Inactivating BAP1 mutations increase the prometastatic behaviour of uveal melanoma cells, although the mechanism by which this occurs remains unknown.24

Mutations associated with a less aggressive behaviour include those found in splicing factor 3B subunit 1 (SF3B1) and eukaryotic translation initiation factor 1A, X-linked (EIF1AX).26 27 These mutations are mutually exclusive to one another in 19% and 24% of uveal melanomas, respectively.26 27 Despite this frequency, SF3B1 or EIF1AX mutations are found in just 3% of uveal melanomas with monosomy 3.27 Furthermore, preliminary whole genome single-nucleotide polymorphism microarray data showed that amplification of CNKSR3, the product of which is thought to be involved in transepithelial sodium transport, correlated with improved survival of patients with primary uveal melanoma.28

Prognostication

Survival prognostication takes into account clinical predictors (basal tumour diameter, tumour...
thickness, ciliary body involvement, extracocular spread), pathological predictors (epithelioid melanoma cytomorphology, presence of extravascular matrix patterns, high mitotic count per 40 high-power fields) and genetic predictors, as described above. Most histopathological indicators show good correlation with metastatic mortality and mathematical methods have been developed to combine the clinical tumour, node, metastasis stage with pathological and genetic prognostic factors. Personalised prognostication is a matter of debate between physicians as many believe that there is no advantage in predicting an unpreventable fatal outcome. However, studies have shown that patients find an uncertain prognosis more stressful than a poor one and accurate prognostication allows special care to be targeted at high-risk patients.

**METASTATIC DISEASE**

Despite the development of effective local therapies, 5-year survival rates (~80%) have not changed in the past three decades and up to 50% of patients develop metastases. No effective adjuvant systemic therapy has been demonstrated to reduce the risk of metastasis, as recently reviewed by Triozzi and Singh. One-year survival of patients with metastases is reported to be 15%, with reported median survival ranging from 4 to 15 months.

**Surveillance to identify high-risk patients**

Given the poor prognosis associated with the development of metastatic disease, early identification of patients, following the treatment of primary disease, who are at high risk of metastasis may be of value and could allow for tailored management of patients. The risk of developing metastatic disease is determined by multiple factors, including tumour size, location and genetic profile. Gene expression profiling tests are one way to determine a patient’s risk of progressing; patients can be classified as class 1 (low metastatic risk) or class 2 (high metastatic risk), with approximately 40% of patients falling into the latter group. Despite being at lower risk, as classified by genomic profiling, approximately 15% of patients with uveal melanoma who experience metastatic disease are class 1; these patients comprise a distinct molecular subgroup to those class 1 patients whose disease does not metastasise, including a striking increase in expression of preferentially expressed antigen in melanoma. Genotypic profiling using multiplex ligation-dependent probe amplification has also proven useful for determining high-risk patients. About 65% of patients defined as high risk relapse within 5 years, suggesting that surveillance of at least this duration should be undertaken.

**Treatment options for metastatic disease**

For those patients who do develop metastatic disease, there is as yet no proven standard of care. Dacarbazine, a chemotherapeutic option for treatment of cutaneous melanoma, has been used for uveal melanoma, despite the inherent differences between these molecularly distinct diseases, and activity has been limited. Other chemotherapeutic regimens including temozolomide, cisplatin, treosulfan, fotemustine and various combinations have been investigated in uveal melanoma with disappointing results to date.

Ipilimumab, a human monoclonal antibody that blocks the cytotoxic T-lymphocyte-associated antigen 4 (CTLA-4), is approved in the USA and Europe for the treatment of advanced, unresectable melanoma. Response rates of ~5%–10% have been reported from evaluations in metastatic uveal melanoma, but evidence of a median overall survival (OS) of 6.0–9.7 months in these trials suggests that responses could be delayed and durable in only a minority of patients. Preliminary data from the phase II GEM-1 trial in treatment-naïve patients suggested more promising response rates than previously reported. However, ipilimumab demonstrated very limited clinical activity in treatment-naïve or...
pre-treated patients with metastatic uveal melanoma in the phase II DeCOG trial; median progression-free survival (PFS) was 2.8 months and median OS was 6.8 months.\(^\text{32}\)

Nivolumab and pembrolizumab, fully human monoclonal antibodies targeting the programmed cell death 1 (PD-1) receptor, are approved in the USA and Europe for advanced melanoma.\(^\text{34-35}\) However, the activity of PD-1 inhibition in uveal melanoma has not yet been well described. Initial assessment of pembrolizumab in seven patients with metastatic uveal melanoma who had progressed on ipilimumab reported a median PFS of \(\geq 3\) months;\(^\text{36}\) a phase II trial in patients with metastatic uveal melanoma is currently recruiting (NCT02339851).

There is a real need for specifically approved treatments and dedicated management strategies in order to improve outcomes for patients affected by this difficult-to-manage disease. Given the limited activity of currently approved agents for advanced melanoma in the treatment of metastatic uveal melanoma, efforts have been placed on conducting clinical trials that have been designed based on our increased understanding of the biology of this disease.

**MEK inhibitor trials in the metastatic setting**

GNAQ\(\text{Q}\)/GNA11 mutations drive the constitutive activation of the RAS-ERK pathway. However, uveal melanomas lack the oncogenic aberrations of this pathway such as BRAF;\(^\text{37}\) which mediate sensitivity to the BRAF inhibitors vemurafenib and dabrafenib in cutaneous melanoma.\(^\text{38,39}\) Given the molecular profile of uveal melanoma, there is a rationale for treatments that target downstream components of the molecular pathways driving tumour growth, including MEK and protein kinase C (PKC).

Reduction of uveal melanoma cell viability with selumetinib (AZD6244, ARRY-142886), an oral, potent and highly selective, allosteric MEK1/2 inhibitor\(^\text{40}\) with a short half-life,\(^\text{61,62}\) was correlated with a MEK-dependent gene signature and found to be greater in tumour cells with GNAQ or BRAF mutations than in wild-type cells.\(^\text{63}\)

In a phase II trial in 101 treatment-naïve or pre-treated patients with metastatic uveal melanoma, treatment with selumetinib resulted in improvements in efficacy outcomes compared with chemotherapy (temozolomide or dacarbazine).\(^\text{43}\) Median PFS was significantly improved with selumetinib (15.9 vs 7 weeks; HR, 0.46 (95% CI 0.30 to 0.71); one-sided \(p<0.001\)). The corresponding response rate was 14% with selumetinib compared with 0% with chemotherapy. No significant improvement in median OS was observed (11.8 vs 9.1 months for selumetinib and chemotherapy, respectively (HR, 0.66; 95% CI 0.41 to 1.06)). However, assessment of OS was confounded by the crossover of 86% of patients from the chemotherapy arm to selumetinib, as it was observed that prior treatment with temozolomide or dacarbazine may affect the efficacy of selumetinib.\(^\text{43}\)

Based on these promising observations, a phase III trial (n=129) to assess the efficacy of selumetinib in combination with dacarbazine in patients with systemic treatment-naïve metastatic uveal melanoma was initiated (SUMIT, NCT01974752).\(^\text{64}\) This was the first clinical trial in uveal melanoma designed with intent to register a drug product with regulatory bodies. However, SUMIT did not meet its primary end point of PFS by blinded independent central review (BICR).\(^\text{65}\) Median PFS was not significantly improved in the selumetinib+dacarbazine arm compared with the placebo+dacarbazine arm (2.8 vs 1.8 months; HR 0.78 (95% CI 0.48 to 1.27); two-sided \(p=0.32\)); the corresponding response rates were 3.1% and 0%, respectively (two-sided \(p=0.36\)). There was a numerical improvement in investigator-determined median PFS in the selumetinib+dacarbazine arm (3.8 vs 2.1 months; HR 0.49 (95% CI 0.28 to 0.84)). Further evaluation of the discrepancies between BICR and investigator-determined PFS and assessment of biomarkers are ongoing. OS data were immature at the time of primary analysis and no further analyses are foreseen based on trial assumptions.

Differences in patient population, study design and notably the addition of dacarbazine to selumetinib in SUMIT, compared with selumetinib monotherapy in the phase II trial\(^\text{43}\) may have led to the differences observed in PFS between the two trials. Further assessment of selumetinib for the treatment of uveal melanoma is ongoing in a trial comparing weekly intravenous paclitaxel 80 mg/m\(^2\) in combination with selumetinib 75 mg and weekly intravenous paclitaxel 80 mg/m\(^2\) in combination with selumetinib 75 mg twice daily with 2 days off prior to each paclitaxel bolus (EudraCT: 2014-004437-22). A second phase I trial is being developed in which selumetinib will be escalated above 75 mg twice daily using an intermittent dosing schedule of 3 days on followed by 4 days off.

Trametinib, another potent MEK1/2 inhibitor, is characterised by different pharmacokinetic properties than selumetinib, including a longer half-life.\(^\text{61,66}\) In a phase I trial in advanced melanoma, trametinib demonstrated limited clinical activity in 16 heavily pre-treated patients with metastatic uveal melanoma, corresponding to a median PFS of 1.8 months and an unconfirmed overall response rate of 0%.\(^\text{67}\) No radiographic responses were observed; two patients achieved 24% tumour reduction and 8 achieved stable disease. Four patients received treatment for \(\geq 16\) weeks; two patients received treatment for \(\geq 24\) weeks.\(^\text{67}\)

Phosphorylated AKT is observed in \(>50\%\) of uveal melanomas and is associated with a higher risk of metastatic disease.\(^\text{68}\) A phase II trial prospectively evaluating the efficacy of trametinib with or without the AKT inhibitor GSK2141795 in patients with metastatic uveal melanoma is ongoing (NCT01979523; table 1). As selumetinib in combination with the AKT inhibitor MK2206 reduced cell viability by \(>50\%\) in multiple GNAQ-mutant uveal melanoma cell lines and reduced tumour volume in mouse xenograft models,\(^\text{69}\) the combination of MEK and AKT inhibition is a treatment strategy of interest.

Activating somatic mutations in GNAQ led to the constitutive activation of the downstream PKC pathway PLC/\(\beta\)PKC/ERK1/2.\(^\text{70}\) Preclinical in vitro models showed a strong sensitivity to synergistic treatment with the MEK inhibitor binimetinib (MEK162) and the PKC inhibitor AEB071 (sotrastaurin), associated with halting of proliferation and induction of apoptosis. The combination also significantly reduced tumour size in a GNAQ-mutant mouse xenograft model.\(^\text{71}\) The combination of binimetinib and AEB071 is being investigated in a phase I/II trial in patients with metastatic uveal melanoma (NCT01801358).

Other trials in the metastatic setting

The multi-targeted tyrosine kinase inhibitor, sunitinib, inhibits driver mutations in the receptor tyrosine kinase, c-Kit. Immunohistochemistry analysis found that c-Kit was expressed in \(\geq 63\%\) of surgical primary uveal melanoma specimens, suggesting that c-Kit may be important in uveal melanoma tumour growth.\(^\text{72}\) Median PFS (2.76 vs 3.88 months (HR, 1.09; 95% CI 0.62 to 1.92)) and OS (6.35 vs 8.65 months (HR, 1.59; 95% CI 0.86 to 2.96)) were not improved with sunitinib over dacarbazine in a phase II trial of 74 patients with metastatic
disease who had received no prior systemic therapy for advanced disease.44

Bevacizumab is an antiangiogenic agent that targets all iso-
forms of vascular endothelial growth factor (VEGF); over-
expression of VEGF in uveal melanoma results in increased
tumour size and angiogenesis.73 74 In preclinical models, beva-
cizumab inhibited VEGF activity, reducing primary ocular mel-
anoma growth and suppressing the formation of hepatic
micrometastases.75 In a retrospective review of uveal mel-
onoma treatments, no signi-
cant survival benefit was seen in
patients treated with bevacizumab.76 No objective responses
were observed in a phase II trial of the combination of bevac-
zumab and temozolomide (n=35); median PFS and OS were 3
months, respectively.77

Activating mutations of GNAQ and GNA11 upregulate the
hepatocyte growth factor, MET, which is implicated in the
metastasis of uveal melanoma.78 Clinical activity in patients
with uveal melanoma has been achieved with cabozantinib, a
non-selective dual MET and VEGF inhibitor.79 Subset analysis
of 23 patients with uveal melanoma treated as part of a phase II
trial revealed a median PFS and OS of 4.8 and 12.6 months,
respectively.77 In a phase II trial of 11 patients with advanced uveal melanoma.

Liver-targeted treatment options
The liver is the organ most commonly affected by metastatic
disease. At the time of death, approximately 90% of patients
have liver metastases; of these, 50% of patients appear to have
metastases exclusively in the liver.81

Although evidence is limited, preliminary data suggest
improvements in patient outcomes following hepatic resection.82

Table 1 Ongoing clinical trials in metastatic uveal melanoma

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Mechanism of action</th>
<th>Phase</th>
<th>Identifier</th>
<th>Trial status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selumetinib+paclitaxel</td>
<td>MEK1/2 inhibitor+chemotherapy</td>
<td>II</td>
<td>EudraCT: 2014-004437-22</td>
<td>Recruiting</td>
</tr>
<tr>
<td>Trametinib+GSK2141795</td>
<td>MEK inhibitor+AKT inhibitor</td>
<td>II</td>
<td>NCT01979523</td>
<td>Recruiting</td>
</tr>
<tr>
<td>Binimetinib+AEB071</td>
<td>MEK inhibitor+PKC inhibitor</td>
<td>III</td>
<td>NCT01801358</td>
<td>Recruitment held</td>
</tr>
<tr>
<td>Cabozantinib</td>
<td>MET inhibitor</td>
<td>II</td>
<td>NCT01835145</td>
<td>Recruiting</td>
</tr>
<tr>
<td>Vorinostat</td>
<td>Histone deacetylase inhibitor</td>
<td>II</td>
<td>NCT01587352</td>
<td>Recruiting</td>
</tr>
<tr>
<td>Sorafenib</td>
<td>Multi-kinase inhibitor</td>
<td>II</td>
<td>NCT01377025</td>
<td>Recruitment complete</td>
</tr>
<tr>
<td>Ganetespib</td>
<td>HSP90 inhibitor</td>
<td>II</td>
<td>NCT01200238</td>
<td>Recruitment held</td>
</tr>
<tr>
<td>Adoptive T-cell transfer</td>
<td>Tumour-infiltrating lymphocytes</td>
<td>II</td>
<td>NCT01814046</td>
<td>Recruiting</td>
</tr>
<tr>
<td>AEB071+BYL719</td>
<td>PKC inhibitor+PI3K inhibitor</td>
<td>Ib</td>
<td>NCT02273219</td>
<td>Recruiting</td>
</tr>
<tr>
<td>AEB071</td>
<td>PKC inhibitor</td>
<td>I</td>
<td>NCT01430416</td>
<td>Recruitment complete</td>
</tr>
<tr>
<td>Pembrolizumab</td>
<td>Anti-PD-1</td>
<td>II</td>
<td>NCT02359851</td>
<td>Recruiting</td>
</tr>
</tbody>
</table>

HSP90, heat shock protein 90; PD-1, programmed cell death 1; PKC, protein kinase C.

region chemotherapy such as hepatic intra-arterial (HIA)
chemotherapy85 and hepatic arterial chemoembolisation.86
Retrospective case studies suggest that surgical resection may be
curative; however, these studies report on highly selected patient
populations and surgery is not suitable for >90% of patients
with liver metastases.87 88 A single trial has compared the efficacy
between HIA and intravenous fotemustine. Although there was
no OS benefit (median 14.6 months for HIA vs 13.8 months for
intravenous fotemustine), improvements in PFS (4.5 vs
3.5 months) and response rate (10.5% vs 2.4%) were observed with
HIA versus intravenous chemotherapy.88

Isolated hepatic perfusion (IHP) involves surgically isolating
the blood supply to the liver to allow direct delivery of high-
dose chemotherapy. In a trial of 34 patients with isolated liver
metastases, the median OS with IHP was 24 months, corre-
ponding to a potential survival bene
fit of 14 months
compared with retrospective controls (p=0.029).89 A phase III
trial comparing IHP with the best alternative care in uveal
melanoma is underway (NCT01785316). A non-surgical alter-
native to IHP is percutaneous hepatic perfusion (PHP). A
phase III trial of PHP with melphalan compared with best
alternative care in 93 patients with ocular (88%) or cutaneous
melanoma demonstrated significantly improved hepatic
PFS and overall response rate with PHP therapy. OS was
similar between the two arms; however, this was confounded
by crossover.90

Localised radioembolisation using yttrium-90 (90Y)-labelled
microspheres has also shown benefit for patients with liver
metastases. In a small trial of 13 patients, partial responses and
stable disease were observed in eight and two patients, respec-
tively.91 The combination of 90Y-labelled microspheres with sora-
fenib is being studied in a phase I trial (NCT01893099) and
combination with ipilimumab is being assessed in a phase 0
study (NCT01730157).

Systemic adjuvant therapy
Adjuvant therapy has not been widely studied in uveal melan-
ona and there is little evidence that any approach improves
patient outcome. However, new approaches to adjuvant therapy
are being developed, including rational use of existing cytotoxic
and immunotherapeutic regimens using tumour genetic criteria
to identify patients at risk. The use of systemic therapy in the
adjuvant setting has been discussed in excellent prior publica-
tions and the readers are referred to these reviews for additional
information.32
Management and surveillance for metastatic uveal melanoma

In most cases of uveal melanoma, patients are diagnosed by an optometrist or ophthalmologist, with subsequent referral to a specialist ophthalmologist. Delays in treatment at this stage can have implications on preventable morbidity and overall patient outcomes. For example, a greater percentage of patients in the UK who experienced delays, or who reported their tumour as being misdiagnosed, ultimately required enucleation. Delays may arise from slow referral times, misdiagnosis or failed detection of tumours, delays in imaging and administrative delays.

Given the frequent development of metastases, consideration of active surveillance and management of patients following adjuvant therapy has been recommended within the UK Uveal Melanoma National Guidelines. Although no survival benefit as a result of the early detection of asymptomatic disease has been documented, surveillance allows for the identification of oligometastatic disease amenable to surgery or other local therapies, as well as patients eligible for clinical trials. Risk stratification by clinical criteria, cytogenetic studies and gene expression profiling can be used to identify patients at high risk of developing metastases and guide surveillance decisions accordingly.

The UK guidelines emphasise the importance of consulting the patient at all stages of their treatment, ensuring individuals are fully informed of any risks, benefits and quality of life implications throughout their treatment and post-treatment surveillance. They recommend that this consultation process should be coordinated by a multidisciplinary team with experience in uveal melanoma treatment, made up of a medical or clinical oncologist, an interventional radiologist, a histopathologist, a liver surgeon and a clinical nurse.

**SUMMARY**

Uveal melanoma is considered rare, but is in fact the most common primary intraocular malignancy in adults. Biologically distinct from cutaneous melanoma, there are a number of underlying somatic gene alterations in uveal melanoma associated with a variable prognosis, which are currently being targeted in clinical drug development. Metastatic disease is associated with a poor prognosis and as such the early identification of patients at high risk of metastases by genetic analysis may allow for personalised management and surveillance. As our understanding of the biology and treatment of this disease develops, multidisciplinary team care will be central to patient management to help optimise outcomes.

**Acknowledgements** The authors thank Jon Moran, PhD, from iMed Comms, who provided medical writing support funded by AstraZeneca.

**Contributors** Defining the concept: RDC. Drafting and critical revision: RDC, GKS, TT, BM, JHF and PDN.

**Funding** AstraZeneca.

**Competing interests** RDC received non-financial support from AstraZeneca, during the conduct of this work; RDC has received grants, personal fees and non-financial support from AstraZeneca; personal fees from Janssen; personal fees from Thompson Reuters; personal fees from Merck; personal fees from Biogen Idec; personal fees from Aura Biosciences; grants from Melanoma Research Foundation; grants from Melanoma Research Alliance; grants from NIH and grants from ASCO; outside the submitted work. PDN reports personal fees from AstraZeneca, outside the submitted work.
REFERENCES


36 Weber JS, D’Angelo SP, Minor D, et al. Nivolumab versus chemotherapy in patients with advanced melanoma who progressed after anti-CTLA-4 treatment...


Metastatic disease from uveal melanoma: treatment options and future prospects

Richard D Carvajal, Gary K Schwartz, Tongalp Tezel, Brian Marr, Jasmine H Francis and Paul D Nathan

Br J Ophthalmol published online August 29, 2016

Updated information and services can be found at:
http://bjo.bmj.com/content/early/2016/08/29/bjophthalmol-2016-309034

These include:

References
This article cites 99 articles, 26 of which you can access for free at:
http://bjo.bmj.com/content/early/2016/08/29/bjophthalmol-2016-309034#BIBL

Open Access
This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections
Articles on similar topics can be found in the following collections

Open access (262)
Eye (globe) (708)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/