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DEVELOPING INNOVATIVE VACCINES



**A Phase Ia study to assess safety and immunogenicity of the *Plasmodium vivax* malaria vaccine candidate Pvs25-IMX313 in Matrix-M1 adjuvant in healthy adults living in the UK**

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2.0	24 Mar 2022	Cyndi Goh Angela Minassian	Rationale for dose selection included for clarity  Language regarding gender and contraception changed to be more inclusive and for clarity  Wording relating to group holding rules amended for clarity  Wording relating to first volunteers amended for clarity  Typographical errors corrected  Removal of reference to form on p5 of GP screening letter

**A Phase Ia study to assess safety and immunogenicity of the *Plasmodium vivax* malaria vaccine candidate Pvs25-IMX313 in Matrix-M1 adjuvant in healthy adults living in the UK**

**Study Code: VAC084**

Chief Investigator Dr Angela M Minassian  
Centre for Clinical Vaccinology and Tropical Medicine  
Jenner Institute  
University of Oxford  
Churchill Hospital  
Old Road  
Headington  
Oxford, OX3 7LE  
Email: angela.minassian@ndm.ox.ac.uk

Investigator Prof Sumi Biswas  
Jenner Institute  
University of Oxford  
Old Road Campus Research Building  
Roosevelt Drive  
Headington  
Oxford, OX3 7DQ  
Email: sumi.biswas@ndm.ox.ac.uk

Trial sites Centre for Clinical Vaccinology & Tropical Medicine  
Jenner Institute  
University of Oxford  
Churchill Hospital  
Old Road  
Headington  
Oxford, OX3 7LE  
PI at Site: Dr Angela M Minassian

Sponsoring Institution University of Oxford  
Research Governance, Ethics and Assurance Team  
Research Services

University of Oxford  
Joint Research Office  
Boundary Brook House  
Churchill Drive  
Headington, OX3 7GB  
Tel: 01865 616480  
Email: ctrg@admin.ox.ac.uk

External Monitor

Appledown Clinical Research Ltd.  
Orchard End  
Greenlands Lane  
Prestwood  
Bucks, HP16 9QX  
Tel: 01494 867676/07941 271635  
Email: ceri.mckenna@appledown.net

Local Safety Monitor

Prof Brian Angus  
Centre for Clinical Vaccinology and Tropical Medicine  
Churchill Hospital  
Old Road  
Headington  
Oxford, OX3 7LE  
Tel: 01865 220289  
Email: brian.angus@ndm.ox.ac.uk

Funder

European Commission (Horizon 2020)  
Rue de la Loi / Wetstraat 170B-  
1049 Brussels  
Belgium

## **Confidentiality Statement**

This document contains confidential information that must not be disclosed to anyone other than the Sponsor, the Investigator Team, and members of the Independent Ethics Committee. This information cannot be used for any purpose other than the evaluation or conduct of the clinical investigation without the prior written consent of Dr Angela M Minassian.

## Investigator Agreement

"I have read this protocol and agree to abide by all provisions set forth therein.

I agree to comply with the principles of the International Conference on Harmonisation Tripartite Guideline on Good Clinical Practice."

Dr Angela Minassian	[redacted for public release]	24 Mar 2022
Chief Investigator	Investigator Signature	Date
Dr Angela M Minassian		

## Conflict of Interest

1. "According to the Declaration of Helsinki, 2008, I have read this protocol, and declare no/the following (delete as appropriate) conflict of interest"

Dr Angela Minassian	[redacted for public release]	24 Mar 2022
Chief Investigator	Investigator Signature	Date
Dr Angela M Minassian		

Details: n/a

2. "According to the Declaration of Helsinki, 2008, I have read this protocol, and declare no conflict of interest"

	[redacted for public release]	
Prof Sumi Biswas		24 Mar 2022
Co-investigator	Investigator Signature	Date
Prof Sumi Biswas		

Details: n/a

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## 1 SYNOPSIS

Title	A Phase Ia study to assess safety and immunogenicity of the <i>Plasmodium vivax</i> malaria vaccine candidate Pvs25-IMX313 in Matrix-M1 adjuvant in healthy adults living in the UK
Trial Centre	Clinical Centre for Vaccinology and Tropical Medicine, Churchill Hospital, Old Road, Headington, Oxford, OX3 7LE, UK
Trial Identifier	VAC084
Clinical Phase	Phase Ia
Design	Open label, single-site, first-in-human, Phase Ia study
Population	Healthy adults aged 18 – 45 years
Sample Size	<p>Total: 24-30 volunteers</p> <p>Group 1: 8-10 volunteers receiving three doses of 10 µg Pvs25-IMX313 in 50 µg Matrix-M1 on days 0, 28 and 56</p> <p>Group 2: 8-10 volunteers receiving three doses of 50 µg Pvs25-IMX313 in 50 µg Matrix-M1 on days 0, 28 and 56</p> <p>Group 3: 8-10 volunteers receiving two doses of 50 µg Pvs25-IMX313 in 50 µg Matrix-M1 on days 0 and 28, followed by one dose of 10 µg Pvs25-IMX313 in 50 µg Matrix-M1 on day 56</p>
Follow-up duration	Participants will be followed for approximately 8 months
Planned trial period	Approximately 11 months from first vaccination of the first volunteer
Primary Objective	To assess safety and tolerability of the Pvs25-IMX313/Matrix-M1 vaccine in healthy adult volunteers
Secondary Objectives	<p>To assess the humoral and cellular immunogenicity of the Pvs25-IMX313/Matrix-M1 vaccine, when administered to healthy adult volunteers in the various regimes</p> <p>To assess <i>ex vivo</i> efficacy of the Pvs25-IMX313/Matrix-M1 vaccine using membrane feeding assays, when administered to healthy adult volunteers</p>

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Investigational Products	<ol style="list-style-type: none"> <li>1. Pvs25-IMX313 - recombinant protein-nanoparticle malaria vaccine candidate</li> <li>2. Matrix-M1 – saponin based vaccine adjuvant</li> </ol>
Form	<ol style="list-style-type: none"> <li>1. Pvs25-IMX313: liquid, stored between -65°C and -90°C</li> <li>2. Matrix-M1: liquid, stored at +2°C to +8°C</li> </ol>
Dose	<p>Group 1:</p> <ol style="list-style-type: none"> <li>a. Pvs25-IMX313 – 10 µg, administered in a three-dose schedule on days 0, 28 and 56</li> <li>b. Matrix-M1 – 50 µg, administered with each Pvs25-IMX313 dose on days 0, 28 and 56</li> </ol> <p>Group 2:</p> <ol style="list-style-type: none"> <li>a. Pvs25-IMX313 – 50 µg, administered in a three-dose schedule on days 0, 28 and 56</li> <li>b. Matrix-M1 – 50 µg, administered with each Pvs25-IMX313 dose on days 0, 28 and 56</li> </ol> <p>Group 3:</p> <ol style="list-style-type: none"> <li>a. Pvs25-IMX313 – 50 µg, administered in a two-dose schedule on days 0 and 28 followed by 10 µg administered in a one-dose schedule on day 56</li> <li>b. Matrix-M1 – 50 µg, administered with each vfs25-IMX313 dose on days 0, 28 and 56</li> </ol>
Route	Intramuscular injection (IM) in the deltoid region of the arm

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## 2 ABBREVIATIONS

AE	Adverse event
AR	Adverse reaction
β-hCG	Beta human chorionic gonadotropin
CCVTM	Centre for Clinical Vaccinology and Tropical Medicine
ChAd63	Chimpanzee adenovirus 63
CHMI	Controlled human malaria infection
CI	Chief investigator
COVID-19	Coronavirus disease 2019
CRF	Case report form
DARC	Duffy antigen receptor for chemokines
DMFA	Direct membrane feeding assay
DNA	Deoxyribonucleic acid
DSUR	Development safety update report
ELISA	Enzyme-linked immunosorbent assay
ELISPOT	Enzyme-linked immunospot assay
FDA	United States Food and Drug Administration
G6PD	Glucose-6-phosphate dehydrogenase
GCP	Good clinical practice
GLA-SE	Glucopyranosyl lipid adjuvant-stable emulsion
GMP	Good manufacturing practice
GP	General practitioner
GSK	GlaxoSmithKline
HBsAg	Hepatitis B surface antigen
HCV	Hepatitis C virus
HIV	Human immunodeficiency virus
HTLV	Human T-lymphotropic virus
HLA	Human leukocyte antigen
ICH	International Conference on Harmonisation
IgG	Immunoglobulin G
IM	Intramuscular
IMP	Investigational medicinal product
kDa	Kilodaltons
LSM	Local safety monitor

mAb	Monoclonal antibody
MFA	Membrane feeding assay
MHRA	Medicines and Healthcare products Regulatory Agency
MVA	Modified vaccinia Ankara
<i>P. falciparum</i>	<i>Plasmodium falciparum</i>
<i>P. vivax</i>	<i>Plasmodium vivax</i>
PCR	Polymerase chain reaction
PHE	Public Health England
PI	Principal investigator
PIS	Participant information sheet
PPE	Personal protective equipment
PvCS	<i>Plasmodium vivax</i> circumsporozoite
PvCSP	<i>Plasmodium vivax</i> circumsporozoite protein
PvDBPII	<i>Plasmodium vivax</i> Duffy-binding protein II
QP	Qualified person
RAS	Radiation-attenuated sporozoites
RBM	Roll back malaria
REC	Research Ethics Committee
RGEA	Research Governance, Ethics and Assurance Team
RNA	Ribonucleic acid
SAE	Serious adverse event
SAR	Serious adverse reaction
SDEA	Safety Data Exchange Agreement
SMFA	Standard membrane feeding assay
SOP	Standard operating procedure
SUSAR	Suspected unexpected serious adverse reaction
TBV	Transmission blocking vaccine
TOPS	The overvolunteering prevention system
TMF	Trial master file
TRA	Transmission reducing activity
UOXF	University of Oxford
VLP	Virus-like particle
VMP001	Vivax malaria protein 1
WHO	World Health Organisation

### 3 BACKGROUND & RATIONALE

#### 3.1 The need for a vaccine against *Plasmodium vivax* malaria

Malaria is a potentially life-threatening parasitic infection and a major public health concern. Globally, 3.4 billion people are thought to be at risk of infection [1, 2], and in 2019 a reported 229 million cases and 409 thousand deaths occurred from this disease [3]. Children under five years of age are the most severely affected, with 67% of all malaria-related deaths occurring in this age group around the world in 2019 [3].

Of the five main species known to infect humans, *Plasmodium vivax* (*P. vivax*) is the most widespread geographically and the second largest contributor to symptomatic malaria worldwide, after *Plasmodium falciparum* (*P. falciparum*). There is endemic transmission of *P. vivax* throughout most of the tropics including Africa, Asia, the South Pacific, and Central and South America; an estimated 82% of cases comes from just four high-burden countries: India, Pakistan, Ethiopia and Sudan [4]. Approximately 2.5 billion individuals, or one-third of the world population are at risk of infection from *P. vivax* and the global burden of symptomatic *P. vivax* infection was estimated to be between 13.7 and 15 million cases in 2017 [4].

Since 2000, following concerted worldwide efforts, there have been huge gains in the global fight against all-cause malaria, leading to a reduction in overall mortality from 736,000 in 2000 to 409,000 in 2019 [3]. However, this has been primarily due to a reduction in the incidence of *P. falciparum* in many areas. In fact, in regions where both parasites co-exist, there has been a steady increase in the proportion of *P. vivax* cases [5-8].

Moreover, there has been a prevailing attitude that *P. vivax* malaria is a relatively benign disease. This is in fact not the case as, unlike *P. falciparum*, *P. vivax* can form a dormant liver stage that can activate even years after the initial infection [9]. This means it is a difficult and recurrent disease to fully treat. In addition, the greatest risk of mortality from *P. vivax* is in vulnerable populations such as young infants and pregnant women suffering from recurrent episodes of malaria, with a cumulative risk of severe anaemia and associated comorbidities [10]. In patients with severe symptomatic disease, mortality remains unacceptably high, with estimates between 5 to 25% [2, 11-14].

The socio-economic impact of this infection is not known, but in terms of overall global cost due to lost productivity, this is estimated at US\$ 1.4 to 4.0 billion per year [15]. Those affected by *P. vivax* malaria are typically poor with inadequate access to affordable healthcare and with little financial reserve, perpetuating the cycle of poverty [16].

Clinical cases not only result from primary infection but also relapses, which occur weeks to years after primary infection. Relapses are due to the ability of the *P. vivax* parasite to remain dormant in the liver in the hypnozoite stage, a lifecycle stage not seen with *P. falciparum* malaria [15]. Standard schizonticidal regimes are not effective against hypnozoites. Thus, radical cure of dormant parasites requires therapy with the 8-aminoquinolone primaquine, currently the only licensed hypnozoitocidal anti-malaria, although tafenoquine, a new drug of the same class, has recently been approved by the United States Food and Drug Administration (FDA). However, both 8-aminoquinolones carry a significant risk of causing severe haemolytic anaemia in individuals who are deficient in the glucose-6-phosphate dehydrogenase (G6PD) enzyme, an inherited X-lined red blood cell enzyme disorder common in tropical and sub-tropical areas [17]. More recently, the importance of the cytochrome P450 enzyme, CYP2D6, in metabolism of primaquine to the active metabolite has been recognised [18, 19]. A common polymorphism in the *CYP2D6* gene for the cytochrome P450 enzyme results in poor conversion of primaquine to the active form, resulting in

higher treatment failure rates. It is estimated that these two factors combined may make nearly 40% of the population at risk of *P. vivax* infection ineligible for primaquine therapy [17].

Despite nearly 20 years of advances, the WHO reports that the progress in decline of global mortality from all-cause malaria has slowed in recent years. Globally, the malaria mortality rate (i.e. deaths per 100,000 population at risk) was reported to be approximately 25 in the year 2000, halving to 12 in 2015, but only improving to 10 in 2019 [20]. Furthermore, current strategies are complicated by the rise in insecticide-resistant *Anopheles* mosquitoes and antimalarial resistant parasite strains in South East Asia and China, underlining the need for new tools for malaria control [21].

The Roll Back Malaria (RBM) Partnership was launched in 1998 by the WHO, the United Nations Children's Fund, the United Nations Development Programme and the World Bank. A major goal of The RBM Partnership is to support the development of vaccines against malaria as a key future strategy for reducing mortality from malaria. The WHO Global Vaccine Research Forum has set out a strategic framework for malaria vaccine development in the Malaria Vaccine Technology Roadmap, defining the goals for global malaria vaccine development community [22]. The Roadmap calls for the development of vaccines against both *P. falciparum* and *P. vivax* by 2030 to achieve two key objectives: protective efficacy of at least 75 percent against clinical malaria and reduction of parasite transmission to substantially reduce incidence of human malaria infection, enabling elimination in multiple settings.

Efforts to develop interventions against *P. vivax* have lagged far behind those for *P. falciparum*, with the majority of malaria research and funding focused on the latter. Unique biological and epidemiological characteristics of *P. vivax* infection mean that control strategies that have been primarily targeted against *P. falciparum* are ineffective. For example, increasing resistance to chloroquine [23] and the unsuitability of primaquine in clinically vulnerable groups (e.g. pregnant women, infants <6 months of age and glucose-6-phosphate dehydrogenase (G6PD) deficient individuals) contribute to poor outcomes from *P. vivax* infection. An effective vaccine strategy against *P. vivax* would be particularly valuable since the dormant parasite makes pharmacological elimination a challenge. However, there are critical bottlenecks in the vaccine development process against this *P. vivax* parasite such as difficulty in long-term culture of *P. vivax* and lack of easy access to a safe controlled human malaria infection (CHMI) model to provide evaluation of vaccine efficacy in humans.

### **3.2 Lifecycle of the *P. vivax* malaria parasite**

In the exoerythrocytic stage of human infection, the bite of an infected female *Anopheles* mosquito transmits malaria sporozoites to the human host where they travel via the bloodstream to the liver and invade hepatocytes (liver-stage). Here, they mature into merozoites contained within liver schizonts, rupturing after 6 to 30 days and causing the release of thousands of merozoites into the bloodstream. In parallel, some infected hepatocytes may form hypnozoites, a quiescent stage in the liver, resulting in dormant disease with a potential to reactivate after many months, a phenomenon unique to *P. vivax* (and *Plasmodium ovale*) infection.

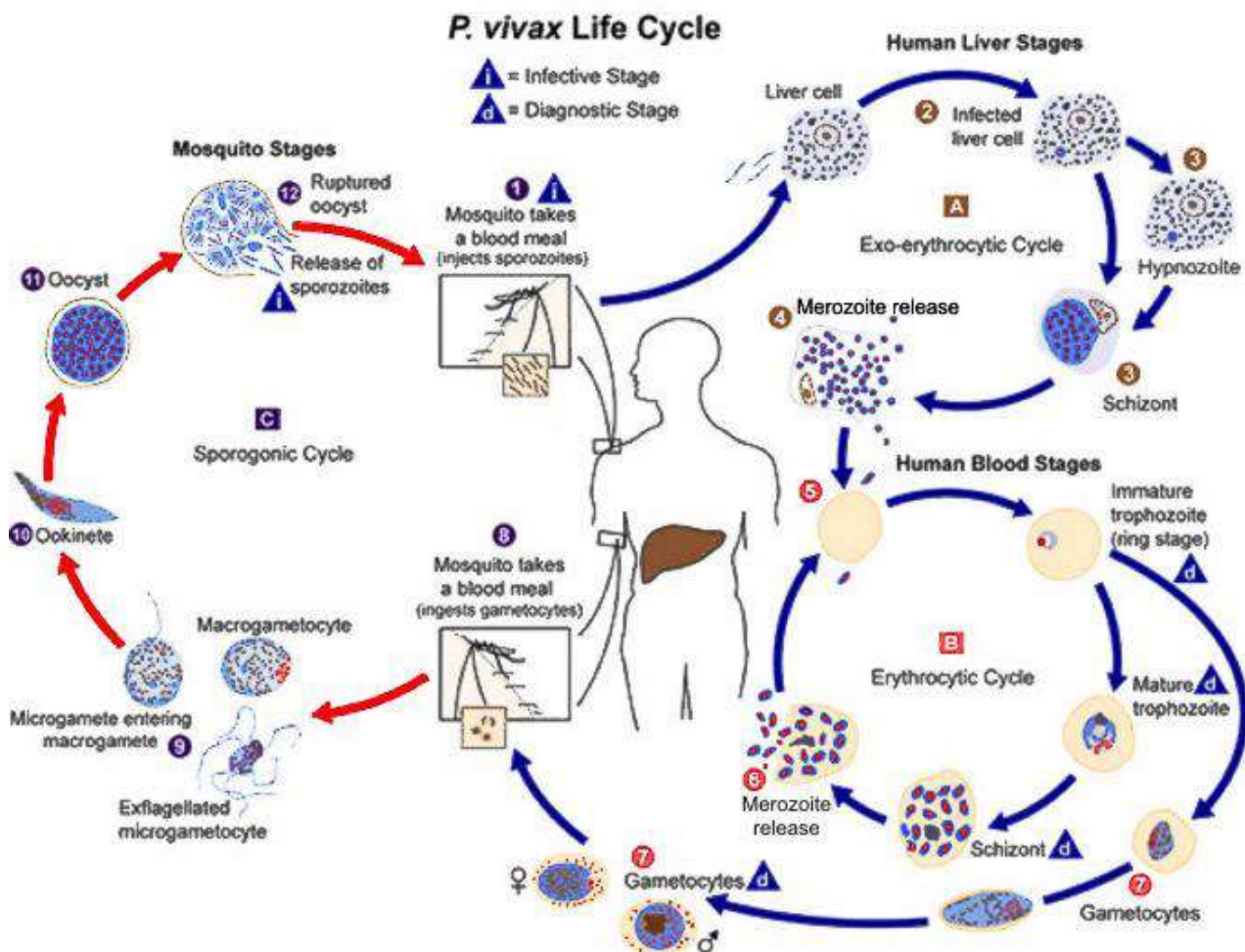
Merozoites then invade reticulocytes (younger, slightly larger erythrocytes) where they multiply and after 48 hours cause the reticulocyte to rupture, releasing progeny merozoites that in turn invade new reticulocytes (blood-stage). It is the blood-stage of infection that is associated with clinical disease and potentially severe or fatal complications. The liver stage is asymptomatic.

During the blood-stage infection, a small percentage of parasites undergo an alternative development pathway, differentiating into sexual male and female gametocyte forms. Over 48



hours, the intra-erythrocytic gametocytes progress through four developmental forms (stages I–IV) before reaching maturity, as stage V gametocytes [24–27]. The earlier stages of sexual development are largely absent from peripheral blood and are thought to sequester extravascularly in the bone marrow, before returning to the circulation as mature Stage V gametocytes [28]. The mature gametocytes are infectious to the mosquito vector, permitting transmission from human to the *Anopheles* host.

Following ingestion by the mosquito at the blood meal, environmental shifts, including changes in temperature and pH, as well as exposure to xanthurenic acid, trigger gametogenesis [29]. The female intra-erythrocytic sexual forms emerge as macrogametes, whilst male gametocytes undergo three rounds of deoxyribonucleic acid (DNA) replication before exflagellation to release 8 motile microgametes [24]. Extracellular macro and microgametes will unite within the mosquito's midgut to undergo fertilisation, forming zygotes, which go on to become motile ookinets that traverse the midgut epithelium. At the basal lamina, following meiotic division, the ookinete further develops into the oocyst. Multiple further rounds of division follow, eventually culminating in rupture of the oocyst and release of sporozoites. The sporozoites subsequently migrate to the mosquito's salivary glands, where they will be injected into the human host at the next blood meal [24–26]. This lifecycle is summarised in Figure 1.



**Figure 1:** Lifecycle of *P. vivax* malaria. Figure reproduced from the Centers for Disease Control and Prevention website [<https://www.cdc.gov/malaria/about/biology/index.html>].

### 3.3 Challenges and directions in *P. vivax* vaccine development

The unique characteristics of *P. vivax* pose specific challenges in studying its biology and designing strategies to control it. For example, the lack of a method for continuous culture of *P. vivax* blood-stages makes it difficult to perform *in vitro* growth inhibition assays to identify synergistic combinations of blood-stage antigens that can be targeted to inhibit *P. vivax* blood-stage growth with high efficiency. Several groups have recently succeeded in establishing short-term *P. vivax* culture for invasion assays using enriched reticulocytes from cord blood [30], but such methods are still dependent on access to fresh *P. vivax* isolates from malaria patients, limiting the routine use of such assays to endemic regions. In the absence of a *P. vivax* blood-stage culture system, production of infected mosquitoes for sporozoite or transmission-stage studies also requires access to *P. vivax* patients in endemic areas.

Currently, the two most clinically advanced *P. vivax* candidates are both subunit vaccines based on *P. vivax* circumsporozoite protein (PvCSP), an analogue of the *P. falciparum* pre-erythrocytic target, which have both reached Phase IIa efficacy testing in mosquito-bite delivered sporozoite *P. vivax* CHMI. The vivax malaria protein 1 (VMP001) vaccine, formulated in the GSK Adjuvant System AS01<sub>B</sub>, was shown to be well-tolerated and immunogenic in healthy US volunteers [31]. However, following CHMI at 14 days after the third immunization, the vaccine failed to induce any sterile protection, although a small but significant delay in parasitaemia was seen in 59% (16/27) volunteers compared to non-vaccinated controls. A Phase IIa trial assessing efficacy of *P. vivax* circumsporozoite protein (PvCS) formulated in Motanide ISA-51 adjuvant in mosquito-bite challenge is also now complete, with results published as a pre-print [32]. This study showed that most volunteers developed PvCS specific antibody and T-cell responses. Following CHMI at 30 days after the third immunization, sterile protection was observed in five of 11 naïve (42%) and four of 11 semi-immune (36%) volunteers by showing no parasitaemia during the 60 days follow-up.

To date, repeated exposure to radiation-attenuate sporozoites (RAS) delivered by mosquito bite has been the only 'immunisation' strategy to demonstrate any protective efficacy in *P. vivax* CHMI. Protection following exposure to irradiated sporozoites was first demonstrated in two volunteers in the 1970's in Maryland, USA [33] but this result was not replicated in larger numbers until a recent study in Cali, Colombia [34]. In the latter study, twelve Duffy-positive participants were exposed to seven 'immunisations', receiving a median of 434 infective bites (range 362-497) from irradiated, infected mosquitoes over 56 weeks. Volunteers were then treated with chloroquine and primaquine to clear any plasmodium infections that may have developed during the immunization phase before challenge at 8 weeks after the last RAS exposure. 'Immunised' participants underwent CHMI alongside two controls, who were Duffy-positive individuals exposed to non-irradiated, non-infected mosquitoes and seven controls who were Duffy-negative individuals who had received the same immunization regime. Sterile efficacy was demonstrated in 42% (5/12) Duffy-positive participants, all of which were female. Given the apparent high-dose exposure required to afford this level of protection, and the current lack of availability of cryopreserved, purified *P. vivax* sporozoites, this approach may be limited as a vaccination strategy. However, transcriptomic and anti-parasite antibody profiling may offer important insights into correlates of protection and new pre-erythrocytic vaccine targets.

Apart from the viral-vectored *Plasmodium vivax* Duffy-binding Protein II (PvDBPII) vaccine candidates [35], the only other *P. vivax* blood-stage vaccine currently in active clinical development is the recombinant protein PvDBPII vaccine. This vaccine targets the cysteine-rich, region II of PvDBP, which serves as the functional receptor-binding domain for the essential interaction for reticulocyte invasion with Duffy antigen receptor for chemokines (DARC). A Phase I trial has

demonstrated that the PvDBPII vaccine, formulated with the glucopyranosyl lipid adjuvant-stable emulsion (GLA-SE), is safe and induces functional strain-transcending antibodies, which inhibit the PvDBP-DARC interaction *in vitro* [36].

All vaccines currently in clinical development, and almost all those in pre-clinical stages, target individual stages of the parasite's life cycle and are based on single antigens (Table 1) [37]. However, the development of an effective vaccine will likely require combination of multiple antigens that provide synergy to achieve high efficacy. For example, achieving high rates of blood-stage growth inhibition may require targeting a combination of key blood-stage antigens involved in reticulocyte invasion. In addition, a combination of blood-stage antigens with liver-stage antigens may be needed to achieve high efficacy, and inclusion of antigens from sexual and mosquito-stages may be needed to inhibit transmission. It is therefore necessary to initiate efforts to combine antigens both within and across developmental stages to achieve synergy and attain the goal of developing a vaccine for *P. vivax* malaria with high efficacy.

Vaccine candidate	Development phase	Lifecycle stage	Antigen	Delivery system
ChAd63-PvTRAP/MVA-PvTRAP [38]	Pre-clinical	Liver-stage	PvTRAP	Prime-boost, viral vectors
CSV-S,S [39, 40]	Pre-clinical	Liver-stage	PvCSP	HBsAg fusion-AS01B
PvCSP-LSP [41-43]	Phase I	Liver-stage	PvCSP	Synthetic peptides-Montanide ISA 720
VMP001 [44]	Phase I/IIa	Liver-stage	PvCSP	Rec. protein-AS01B
ChAd64-PvAMA1/MVA-PvAMA1 [45]	Pre-clinical	Blood-stage	PvAMA1	Rec. protein-adjuvant
PvDBPII-DEK <sup>null</sup> [46]	Pre-clinical	Blood-stage	PvDBP	Rec. protein
PvMSP1 <sub>19</sub> [47, 48]	Pre-clinical	Blood-stage	PvMSP1	Rec. protein-Montanide ISA720
PvDBPII [49, 50]	Phase I	Blood-stage	PvDBP	Rec. protein-GLA-SE
ChAd63-PvDBPII/MVA-PvDBPII [51]	Phase I/IIa	Blood-stage	PvDBP	Prime boost, viral vectors
PvDBPII/Matrix-M1 [NCT04201431]	Phase I/IIa	Blood-stage	PvDBP	Rec. protein-adjuvant
AnAPN1 [52]	Pre-clinical	Mosquito midgut Ag	AnAPN1	Rec. protein-adjuvant
Pvs28 [53]	Pre-clinical	Transmission-stage	Pvs28	Rec. protein-adjuvant
Pvs25H [54, 55]	Phase Ia END	Transmission-stage	Pvs25	Rec. protein-Alhydrogel; Rec. protein-Montanide ISA 51

**Table 1:** *P. vivax* vaccine candidates under development. Adapted from Mueller *et al* (2015) [37]. Rec=recombinant.

### 3.4 Rationale for a transmission blocking vaccine against *P. vivax* malaria

Transmission blocking vaccines (TBVs) aim to induce antibodies against sexual-stage antigens. These include antigens expressed during the gametocyte stages (inside RBCs) in humans and also antigens that are exclusively expressed once the parasite is in the mosquito midgut (gametes, zygotes and ookinetes). The induced antibodies are taken up in the blood meal and act to prevent sexual development in the mosquito host, thus blocking onward malaria transmission. Uniquely, TBVs do not aim to provide protection against infection or disease in the vaccinated individual but instead to reduce risk of infection at the community and population level, through interruption of the transmission cycle. It is widely accepted that in order to eliminate and eventually eradicate malaria, a multi-stage malaria vaccine will be required and a TBV will be an essential component for this [56]. In addition to reducing transmission, a TBV can also be used to combat the spread of parasite strains that might arise from immune or vaccine pressure.

The first observations of transmission blocking immunity were reported in 1958, when lower infectivity to mosquitoes of the avian *Plasmodium* spp., *P. fallax* and *P. gallinaceum*, were described in turkeys and chickens which had been immunised with formalin-killed parasitised gametocytes [57] [57] [57]. However, it was not until almost 20 years later, in 1976, that the phenomenon was reproduced, and the underlying mechanism delineated as antibody mediated inhibition of sexual parasite development in the mosquito midgut [58]. In 1983, following developments in methods for *in vitro* culture of the sexual stages of *P. falciparum*, mice were immunised with *P. falciparum* gametes leading to the generation of the first transmission-blocking monoclonal antibodies (mAbs), which could arrest parasite development in the mosquito midgut [59, 60]. Through surface radioisotope labelling of gametes followed by precipitation with these transmission-blocking mAbs, the first list of transmission-blocking targets were identified [60].

The gold standard *ex vivo* model for establishing transmission-reducing (conferring decreased oocyst intensity) or transmission-blocking (reduction in mosquito infection prevalence) effects, is the standard membrane feeding assay (SMFA), wherein mosquitoes are fed cultured gametocytes in the presence of whole serum or purified IgG, from either a test or control source. Mosquitoes are then dissected approximately one week later and oocyst development in the mosquito is quantified by microscopic visualisation using mercury-bromide staining and compared between intervention and control groups. Since *P. vivax* parasites cannot be cultured, direct membrane feeding assays are done where the source of the parasite is infected individuals in endemic regions.

### 3.5 Pvs25 as an antigen

Pvs25 is a member of the P25 family of cysteine-rich 25 kDa proteins. The ookinete plasma membrane of all *Plasmodium* species has approximately 10-15 proteins on its surface, of which two predominate: P25 and P28 [61]. Pvs25 is present in the *P. vivax* species, and has an important role for parasite survival in the mosquito midgut, as well as possible role in traversal of the midgut epithelium [61-63]. Based on structural analyses, the Pvs25 molecule is thought to be triangular and flat, and extensively expressed on the ookinete surface, forming a protective interlocking sheet [64].

Pre-clinical studies in rodent models show that Pvs25 produced in a plant-based system fused to a modified lichenase carrier protein (Pvs25-FhCMB) produced an *in vivo* transmission blocking effect of up to 65% reduction in intensity and 54% reduction in prevalence when used with Abisco-100 adjuvant. In addition, when this platform was combined with heterologous prime-boost

vaccination with viral vectors expressing Pvs25, there was a 74% reduction in intensity and 54% reduction in prevalence. This observation was confirmed by direct membrane feeding assays [65]. Additionally, studies of the *P. falciparum* equivalent, Pfs25, provide further insights into the potential of Pvs25 to be a suitable TBV candidate. Since identification as a target of very effective transmission-blocking mAbs in BALB/c mice, Pfs25 has been extensively tested pre-clinically as a TBV candidate, reliably demonstrating that vaccine-induced Pfs25-specific IgG are effective in blocking transmission [60, 66-68].

### 3.6 Clinical trials of Pvs25-based vaccines

The first clinical evaluation of a *P. vivax* transmission-blocking vaccine was in a 2005 Phase 1a clinical trial of the Pvs25 antigen formulated in Alhydrogel® [54]. The Pvs25 antigen was expressed in *Saccharomyces cerevisiae*, purified, and adsorbed onto Alhydrogel®. Amongst the 10 volunteers in each of the three dose groups (5, 20 and 80 µg) evaluated, the vaccine was found to be well-tolerated with no serious adverse reactions observed. However, there was only modest transmission reducing activity (TRA) detected (no transmission blocking activity) in the membrane feeding assays, with degree of reduction correlating with antibody concentration.

This result prompted efforts to investigate enhancement of antibody responses using a more potent adjuvant [55]. Here, in a Phase 1a clinical trial setting, Pvs25 expressed in *S. cerevisiae* was evaluated alongside the *P. falciparum* homolog, Pfs25 produced in *Pichia pastoris*. Both antigens were formulated in Montanide ISA 51 adjuvant and participants received either of the two vaccine candidates. However, observed suspected unexpected serious adverse reactions led to early cessation of the clinical trial. Two volunteers developed erythema nodosum at 18 days after vaccination with Pvs25/ISA 51 whilst two further volunteers developed a leukaemoid reaction deemed possible related to vaccination. One of these was at 14 days following vaccination with Pfs25/ISA 51 and the other was at 120 days following vaccination with Pvs25/ISA 51. High local reactogenicity was also seen, including acute local tenderness and swelling as well as induration at approximately 2 weeks after vaccination. Given that the systemic reactions were seen with Pvs25, previously well tolerated with Alhydrogel®, and that no previous severe systemic reactions had been reported for Montanide ISA 51, the severe systemic reactogenicity was deemed to be related to the specific antigen/adjuvant combination.

### 3.7 IMX313

IMX313 is based on a chimeric version of the oligomerization domains from chicken complement inhibitor C4-binding protein (C4bp), and forms homogeneous, self-assembling heptamers of the antigen fused to it. IMX313 is a 55 amino acid sequence with less than 20% homology to the sequence of the human protein. This C4bp oligomerization domain has been shown to spontaneously form soluble heptameric structures (termed nanoparticle in this study) when expressed in *E. coli*, and protein antigens fused to these domains have been shown to improve antibody responses over the same amount of monomeric antigen. In addition, mice immunized with the blood-stage malaria vaccine candidate antigen MSP1<sub>19</sub> fused to IMX313 (expressed in *E. coli*) were protected against challenge with a lethal dose of *P. yoelii* parasites [69]. Immunisation of mice and non-human primates with the *Mycobacterium tuberculosis* antigen 85A fused to IMX313 in both DNA vaccines and viral vectors also demonstrated that IMX313 enhances T-cells responses, with consistent increases in both CD4+ and CD8+ T cell responses [70]. Fusion of IMX313 with Pvs25 leads to formation of immunogenic heptamers, which may be expressed in situ when encoded within recombinant viral vectors or as a secreted protein-nanoparticle in *Pichia pastoris*, within a single expression system.

Clinically, IMX313 was first assessed in the recombinant MVA85A-IMX313 tuberculosis vaccine candidate, administered intradermally, in a Phase Ia trial at the Jenner Institute in Oxford. In this first-in-human, dose escalation study, a total of 18 volunteers received MVA85A-IMX313, with 6 receiving a dose of  $1 \times 10^7$  pfu prior to enrolment of the next groups who received either MVA85A-IMX313 or MVA85A, both at a dose of  $5 \times 10^7$  pfu. There were no safety concerns and no significant difference in the number of adverse events (AEs) between the MVA85A-IMX313 group and the MVA85A group, with the majority of AEs (both local and systemic) being mild in nature, although there were no significant differences in immunogenicity between MVA85A and MVA85A-IMX313 groups [70]. Subsequently, a Phase Ia study assessing the ChAd63/MVA Pfs25-IMX313 candidate [study number: NCT02532049] was conducted, demonstrating favourable safety and tolerability for the vaccine [71]. Here, the vaccine was well tolerated at all dose levels tested, with most local and systemic adverse events being mild in severity, no apparent increase in adverse events with boost vaccination and no participants withdrawn due to AEs.

## **4 PVS25-IMX313/MATRIX-M1 VACCINE DEVELOPMENT**

### **4.1 Characteristics of Pvs25-IMX313/Matrix-M1**

Pvs25-IMX313 is a protein-nanoparticle vaccine based on the *P. vivax* transmission-blocking target antigen Pvs25, genetically fused to the IMX313 oligomerization domain. The Pvs25 protein is based on the sequence from the Sal I *P. vivax* strain [72]. The recombinant protein-nanoparticle is expressed and secreted in the *Pichia pastoris* expression system [73].

Matrix-M1 is a potent, saponin-based adjuvant, comprising partially purified extracts of the bark of the *Quillaja saponaria* Molina tree, phosphatidylcholine and cholesterol, formulated as a 40nm-sized complex. Matrix-M has been shown to efficiently activate and recruit immune cells to the draining lymph node, including T-cells, B-cells, NK-cells, dendritic cells and granulocytes, which may lead to enhanced antigen presentation [74]. Matrix-M1 has demonstrated a favourable safety profile, as well as the enhancement of cellular and humoral immune responses to a range of vaccine [74-76].

Pvs25-IMX313 and Matrix-M1 adjuvant will be mixed immediately prior to administration for co-administration.

### **4.2 Vaccine development strategy**

The clinical development of Pvs25-IMX313 in Matrix-M1 adjuvant is aimed towards the production of an effective transmission-blocking malaria vaccine for individuals in malaria endemic regions. This vaccine would be used in a three-dose vaccination regimen.

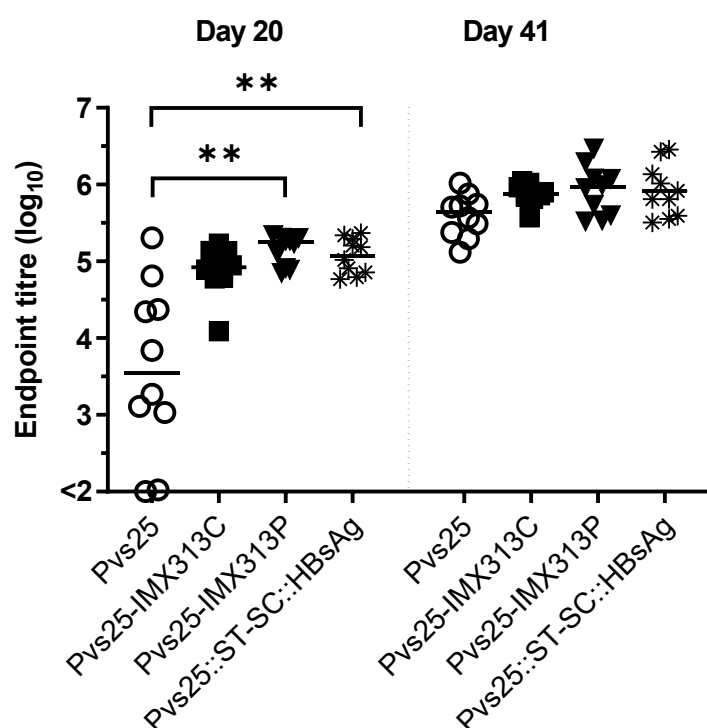
This first-in-human study aims to provide an initial assessment of the frequency and magnitude of adverse events following vaccination with Pvs25-IMX313 in the Matrix-M1 adjuvant for evaluation of safety, as well as immunogenicity and *ex vivo* efficacy via DMFA. Data generated from this study will inform progression to a Phase Ib trial in an endemic region to evaluate the safety and immunogenicity of Pvs25-IMX313/Matrix-M1 at three doses, in a dose-escalation study, to establish the optimal dose and schedule in an endemic setting.

### **4.3 Pvs25-IMX313 immunogenicity and *ex vivo* efficacy in pre-clinical studies**

The addition of the IMX313 domain to the Pvs25 protein allows heptamerization of the protein. This heptameric form has been shown to be significantly more immunogenic than monomeric Pvs25 in preclinical studies involving mice. Purified IgG from immunized mice efficiently inhibits parasite development in mosquito stages as analysed by DMFA.

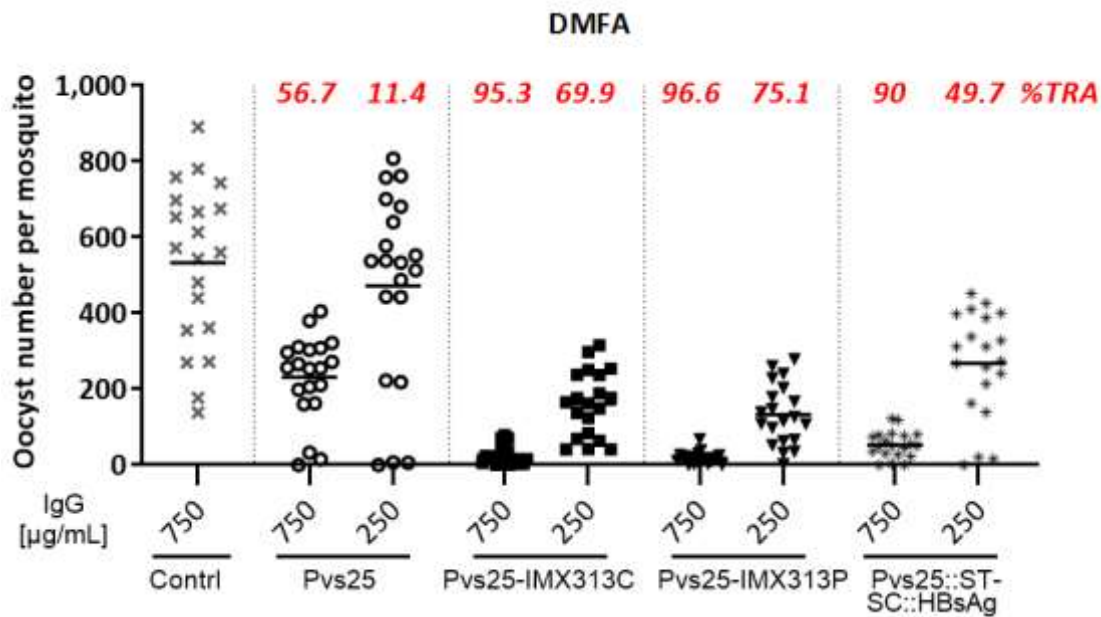
In pre-clinical studies, when formulated with Alhydrogel, Pvs25-IMX313 constructs induced significantly higher antibody titres than Pvs25 alone in CD1 mice after one immunisation (Figure 2). Two variants of Pvs25-IMX313 were compared in this study, they were different only in the purification tags fused at the C terminus of the construct and exhibited no obvious difference in the antibody response induced. Furthermore, Pvs25-IMX313 constructs were able to induce similar levels of antibody response compared to constructs using Pvs25 displayed on virus-like-particles (VLPs), namely HBsAg (Figure 2).





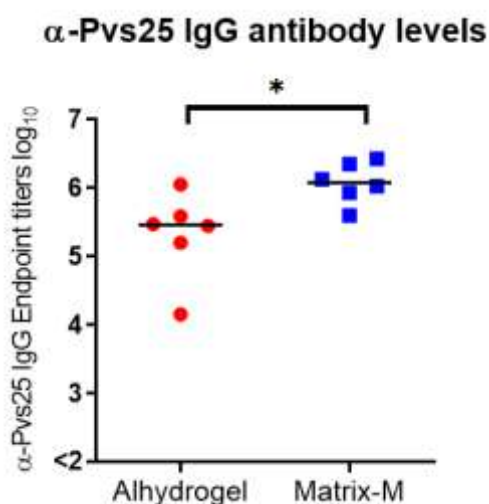
**Figure 2. IMX313 oligomerization enhances Pvs25 immunogenicity:** CD1 mice were immunized with 1 µg (based on total protein content) of Pvs25-IMX313C, or Pvs25-IMX313P, or Pvs25::SpyTag-SpyCatcher::HBsAg, or soluble Pfs25 antigen. All vaccines were formulated with Alhydrogel. Mice received 2 doses, 3 weeks apart (on day 0 and 21), and were sacrificed three weeks after the second dose (day 41). Anti-Pvs25 IgG levels were measured by endpoint ELISA. Each symbol represents serum sample from an individual mouse; lines represent the median of each group. Kruskal-Wallis with Dunn's multiple comparisons test was performed to compare the three groups at the different timepoints: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . ST = SpyTag; SC = SpyCatcher.

Based on functional activity as assessed by DMFA (results were read as TRA where higher values are better), the quality of the anti-Pvs25 antibody response induced by immunisation with both of the Pvs25-IMX313 protein-nanoparticles were significantly improved in comparison to that induced by soluble Pvs25 (Figure 3). Furthermore, at 250 µg/mL IgG concentration, both of the Pvs25-IMX313 constructs demonstrated higher %TRA than the construct using Pvs25 displayed on VLP (Figure 3).



**Figure 3 Pvs25-IMX313 induce IgG with higher TRA than soluble Pvs25:** CD1 mice were immunized with 1 µg (based on total protein content) of Pvs25-IMX313C, or Pvs25-IMX313P, or Pvs25::SpyTag-SpyCatcher::HBsAg, or soluble Pfs25 antigen, formulated with Alhydrogel. Mice received 2 doses, 3 weeks apart (on day 0 and 21), and were sacrificed three weeks after the second dose (day 41). Transmission-reducing efficacy of IgG induced by the vaccines was tested by DMFA: total IgG was purified from the pooled serum of each group (3 weeks post-boost), and the purified IgG was mixed with *P. vivax* gametocytes at concentrations indicated on the X-axes, and fed to *A. stephensi* mosquitoes (n=20 per test group). IgG from ovalbumin-immunized mice was used as a negative control (Contrl). Midguts were dissected 7 days post-feeding. Data points represent the number of oocysts in individual mosquitoes; and lines show the arithmetic mean. Immunization groups are indicated on the X axis. TRA = Transmission-reducing activity (% inhibition in mean oocyst count per mosquito). ST=SpyTag. SC = SpyCatcher.

In addition, Matrix-M and Alhydrogel have been compared head-to-head for formulation with Pvs25-IMX313. In our preclinical studies, Matrix-M was able to induce a higher antibody response compare to Alhydrogel in CD1 mice (Figure 4).



**Figure 4. IMX313 oligomerization and Matrix-M adjuvant enhance Pvs25 immunogenicity:** CD-1 mice received 3 doses of 0.1 µg Pvs25-IMX313, formulated with either Alhydrogel or Matrix-M. Injections at day 0, 1 month, 2 months. Data represented here are from 2 weeks post 3rd immunization. Anti-Pvs25 IgG levels were measured by endpoint ELISA. Each symbol represents the median of the group. Mann-Whitney test (2-tailed);  $p = 0.015$

#### 4.4 Clinical experience with Pvs25-IMX313/Matrix-M1

There is no prior clinical experience with the Pvs25-IMX313 protein in the Matrix-M adjuvant. The Pfs25-IMX313 insert, however, has been clinically tested in a viral vectored vaccination regimen ChAd63/MVA Pfs25-IMX313 in a previous Phase Ia clinical trial in Oxford, completed in May 2017 (VAC062; NCT02532049). The Pvs25-IMX313 construct is exactly the same as the Pfs25-IMX313 construct, except for a difference in the sequence of the 25 gene which enables the vaccine to target *P. vivax* instead of *P. falciparum*.

A total of twenty-six volunteers were vaccinated with ChAd63 Pfs25-IMX313, at doses of either  $5 \times 10^9$  vp ( $n=5$ ) or  $5 \times 10^{10}$  vp ( $n=21$ ). Sixteen volunteers went on to receive a boost with MVA Pfs25-IMX313 on day 56, of which half received a dose of  $1 \times 10^8$  pfu and half a  $2 \times 10^8$  pfu dose. All vaccinations were administered intramuscularly. The ChAd63 Pfs25-IMX313 and MVA Pfs25-IMX313 vaccines were demonstrated to be safe and well-tolerated at all doses, with the majority of AEs being mild in nature. Priming vaccination with  $5 \times 10^{10}$  vp ChAd63 Pfs25-IMX313 followed by MVA Pfs25-IMX313 boost at either dose induced antigen-specific IgG responses in all volunteers, to levels which were significantly higher than following prime alone. However, titres of anti-Pfs25 IgG antibody responses were low with the peak response at 10.24 µg/mL on day 74. Pfs25-specific T cell responses were also detected in all volunteers, as well as Pfs25-specific B cell responses. The functional activity of vaccine-induced antibody responses were assessed by SMFA. With a median TRA of 7.2% (range -5.8% to 37.3%) in the group boosted with the lower dose of MVA and 25.3% (range 10.2% to 41.3%) in the higher MVA dose group, overall TRA was low, with serum from only 1/8 individuals boosted with the higher MVA Pfs25-IMX313 dose demonstrating weak but significant reduction in oocyst intensity. TRA correlated with anti-Pfs25 antibody concentrations (Spearman  $r = 0.5176$ ;  $P = 0.0423$ ). Given that previous human trials have indicated that high levels of specific IgG are required for induction of significant transmission reducing activity, it is likely that lack of TRA observed relates to the low titres of anti-Pfs25 antibodies (a maximum of around 10 µg/mL) induced by immunisation with ChAd63/MVA Pfs25-IMX313.

As expected, due to limited similarity between IMX313 and human C4bp, there were no detectable vaccine-induced auto-reactive antibody or T-cell responses to the oligomerisation domain of human C4bp in any of the study groups [71].

The Pfs25-IMX313/Matrix-M1 vaccine was previously approved for testing in a clinical trial (VAC077; NCT: 04130282). A single volunteer was recruited to the trial and vaccinated with no significant adverse events. However, the trial had to be terminated due to the COVID-19 pandemic. A similar, larger Phase 1 study (VAC082; NCT: 04271306) is currently being conducted at the Ifakara Health Institute in Bagamoyo, Tanzania. This study aims to evaluate the safety, immunogenicity and *ex vivo* efficacy of Pfs25-IMX313/Matrix-M1 in healthy adults and young children. Although recruitment is still in the early stages, there have been no safety concerns thus far.

Matrix-M adjuvant, in 1 or 2 formulations (named Matrix-M1 or Matrix-M2), has been administered to tens of thousands of individuals in clinical trials across the USA, Europe and Australia. In addition to trials involving vaccines to respiratory syncytial virus, influenza and SARS-CoV-2, two malaria pre-erythrocytic candidate vaccines (ChAd63/MVA ME-TRAP and VLP R21) have been administered with Matrix-M1 adjuvant in four phase I and phase I/II trials conducted in Oxford and Burkina Faso (ClinicalTrials.gov identifiers: NCT02572388, NCT02925403, NCT01669512, NCT02905019). A phase III trial involving 4800 children has recently started in Africa with sites in Burkina Faso, Mali, Kenya and Tanzania. Available safety data demonstrates that the Matrix-M adjuvant is well-tolerated with acceptable short-term reactogenicity and unremarkable long-term safety profile with no suspected unexpected serious adverse reactions (SUSARs) in COVID-19 vaccine clinical trials conducted by Novavax collaborators in subjects who received Matrix-M [77].

The profile of adverse events following vaccination with Pfs25-IMX313 may be partially predicted from previous studies assessing protein vaccines using the Matrix-M adjuvant. Local adverse events are likely to include injection site pain, erythema, swelling, itching and warmth. Forseeable systemic adverse events would include headache, fatigue, myalgia, arthralgia, malaise, feverishness, fever and nausea.

## **5 INVESTIGATIONAL PRODUCTS**

### **5.1 Pvs25-IMX313**

#### **5.1.1 Vaccine supply**

Pvs25-IMX313 is manufactured by GenIbet (Oeiras, Portugal), where the vaccines are formulated and vialled. Xerimis Ltd (Reading, UK) will perform certification and QP release, labelling and storage of the Pvs25-IMX313 for investigational use only, and later supply to the clinical site (CCVTM).

#### **5.1.2 Vaccine formulation and packaging**

Pvs25-IMX313 protein drug product is formulated in 20 mM Tris, 150mM NaCl, pH 7.4 (adjusted by sodium hydroxide), at not less than 0.25 mg/ml. The final 0.2 µm filtered drug product was dispensed manually using an electronic dispenser preset to deliver 500 µl into type 1, 2 ml glass vials. The vials were sterilized and depyrogenated with a 13 mm grey bromobutyl rubber stopper supplied by Adelphi Healthcare Packaging (Haywards Heath, UK) and a 13 mm complete tear off, clear lacquered aluminium seal. The containers and closures were tested for compliance with defined specifications.

#### **5.1.3 Storage of Vaccines**

All vaccines will be stored between -65°C and -90°C. All movements of the study vaccines will be documented. Vaccine accountability, storage, shipment and handling will be in accordance with relevant local Standard Operating Procedures (SOPs) and forms.

### **5.2 Matrix-M1**

#### **5.2.1 Matrix-M1 supply**

Matrix-M1 will be supplied to Xerimis by Novavax AB (Uppsala, Sweden), a subsidiary of Novavax, Inc (Gaithersburg, USA), where the adjuvant is formulated and vialled. Matrix-M1 will be labelled for investigational use only by Xermis Ltd before supplying the adjuvant to the clinical site.

All adjuvants will be certified for release by a qualified person (QP) at Xerimis Ltd.

#### **5.2.2 Matrix-M1 formulation and packaging**

Matrix-M1 is formulated at a concentration of 0.375mg/ml in PBS. The drug product is filled into sterile 3 mL glass vials. Matrix-M1 (85 parts Matrix A and 15 parts of Matrix C) is obtained by simply mixing Matrix A and C, followed by dilution in PBS, filtration through a 0.22 µm filter and filling into vials in a volume of 0.75 ml. Matrix-M1 is a slightly brown to colourless, slightly opalescent, non-viscous liquid.

#### **5.2.3 Matrix-M1 Storage and Handling**

Matrix-M1 is stored refrigerated at 2 to 8°C and protected from light. All movements of the adjuvant will be documented. Accountability, storage, shipment and handling of Matrix-M1 will be in accordance with relevant local SOPs and forms.

### **5.3 Administration of Pvs25-IMX313 in Matrix-M1 adjuvant**

A mixture of Pvs25-IMX313 at a dose of 10 µg or 50 µg, with 50 µg of Matrix-M1 will be administered to all volunteers. Matrix-M1 and Pvs25-IMX313 will be mixed immediately prior to

administration and will be administered intramuscularly within one hour of thawing of Pvs25-IMX313.

All vaccines will be administered intramuscularly in the deltoid muscle of the non-dominant arm preferentially, according to SOP VC002 Vaccination. The vaccinating investigator will wear gloves and eye protection. During administration of the vaccines, Advanced Life Support drugs and resuscitation equipment will be immediately available for the management of anaphylaxis. On vaccination day, vaccines will be allowed to thaw to room temperature and administered within 1 hour. A single vial of vaccine will be used per dose administered and any remaining vaccine not used will be discarded.

## 6 OBJECTIVES AND ENDPOINTS

### 6.1 Primary Objectives

To assess safety and tolerability of the Pvs25-IMX313/Matrix-M1 vaccine in healthy adult volunteers.

#### 6.1.1 Primary Outcome Measures

The specific endpoints for safety and reactogenicity will be actively and passively collected data on adverse events. The following parameters will be assessed:

- Occurrence of solicited local reactogenicity signs and symptoms for 7 days following each vaccination
- Occurrence of solicited systemic reactogenicity signs and symptoms for 7 days following each vaccination
- Occurrence of unsolicited adverse events for 28 days following the vaccination
- Change from baseline for safety laboratory measures for 28 days following vaccination
- Occurrence of serious adverse events during the whole study duration

Solicited and unsolicited AE data will be collected at each clinic visit. It will be collected from e-diary cards, clinical review, clinical examination (including observations) and laboratory results. This AE data will be tabulated, detailing frequency, duration and severity of AEs.

Haematological and biochemical laboratory values will be presented according to local grading scales. Serious adverse events (SAEs), adverse events (AEs) of special interest and withdrawal due to AE(s)/SAE(s) will be described in detail. Volunteers will be followed for approximately 8 months following initial dose of Pvs25-IMX313/Matrix-M1 and approximately 6 months following the third dose.

### 6.2 Secondary Objectives

To assess the humoral and cellular immunogenicity of the Pvs25-IMX313/Matrix-M1 vaccine, when administered to healthy adult volunteers.

To assess *ex vivo* efficacy of the Pvs25-IMX313/Matrix-M1 vaccine, when administered to healthy adult volunteers.

#### 6.2.1 Secondary Immunological Outcome Measures

Pvs25-specific immunogenicity will be assessed by a variety of immunological assays, with comparison before and after vaccination. The main outcome measures will be humoral and B cell responses to the Pvs25 protein – total IgG, isotypes and avidity; T cell responses to Pvs25 by *ex vivo* enzyme-linked immunospot assay (ELISpot) and flow cytometry assays.

*Ex vivo* functional blocking activity of purified IgG against *P. vivax* will be assessed by membrane feeding assays .

Other established and exploratory immunology assays may be carried out, which may include collaboration with other specialist laboratories within or beyond Europe. This would involve transfer of serum/plasma, but samples would be anonymised. Volunteers will be consented for this.

The secondary timepoints will be days 1, 29, 57, 140 and 240.

## 7 DESCRIPTION AND JUSTIFICATION OF STUDY DESIGN

### 7.1 Study rationale

As outlined above, the currently available methods for preventing and treating malaria remain inadequate. Although focused efforts have led to substantial reductions in morbidity and mortality worldwide, progress has now stalled. An effective vaccine against *P. vivax* would contribute substantially to disease control and elimination efforts. Currently, only a limited number of *P. vivax* candidate vaccines have reached clinical trials (summarised in Table 1). These include two vaccines targeting the pre-erythrocytic stage, both of which target the *P. vivax* circumsporozoite protein (PvCSP) [31, 42]. CHMI efficacy data for only one of these candidates, VMP001/AS01<sub>B</sub>, is currently published [31] and whilst the vaccine was well-tolerated and immunogenic, there was limited efficacy following sporozoite challenge. In addition, a blood-stage vaccine targeting region II of the *P. vivax* Duffy-binding protein (ChAd63-MVA PvDBP\_RII) has been studied in a Phase 1a study [35] and been shown to be well-tolerated with a favourable safety profile and immunogenicity. A related vaccine targeting the PvDBP region but formulated in Matrix-M1 is currently being studied in a Phase I/IIa study [VAC079, NCT04201431]. As part of the same European Commission grant funding the VAC084 study, a blood-stage vaccine is also being developed with the aim that blood-stage and TBV components will be combined later to develop a multi-stage vaccine.

Although Pvs25-IMX313 in Matrix-M1 has not previously been studied in humans, the *P. falciparum* equivalent, Pfs25-IMX313 in Matrix-M1, is currently undergoing Phase 1 study at the Ifakara Health Institute, Bagamoyo, Tanzania.

This small, first-in-human study will provide initial data on the safety profile of vaccination with Pvs25-IMX313 in the Matrix-M1 adjuvant, as well as immunogenicity and *ex vivo* efficacy via membrane feeding assays.

### 7.2 Rationale for selected doses

The two doses of 10 µg and 50 µg Pvs25-IMX313 in 50 µg Matrix-M were selected on the basis of experience with other candidate protein vaccines which have been tested at the same dose in humans with the same adjuvant. These include the VAC077 and VAC082 trial of Pfs25-IMX313 in Matrix-M1 which is structurally very similar to Pvs25-IMX313.

Mouse studies suggest that a vaccine dose of up to 250 µg/kg is safe. In this study we are testing a maximum dose of 50 µg Pvs25-IMX313 in 50 µg Matrix-M. This is equivalent to a dose of 0.8 µg/kg in humans. This means that there is a safety margin based on body weight of  $250/0.8 = 312$ -fold in humans as compared to mice.

### 7.3 Study Overview

This is an open-label, single-centre, non-randomised, first-in-human Phase Ia study to assess the safety and immunogenicity of the Pvs25-IMX313 vaccine, administered in Matrix-M1 adjuvant.

Up to 30 healthy, malaria-naïve adults aged between 18 and 45 years will be recruited into one of three groups (n=8-10 per group) at the Centre for Clinical Vaccinology and Tropical Medicine (CCVTM), Oxford over approximately 11 months.

All volunteers will receive three doses of Pvs25-IMX313 at 10 µg or 50 µg, in 50 µg Matrix-M1, administered intramuscularly and given four weeks apart. Enrolment will be staggered. Initially, a single volunteer from Group 1 will receive the first vaccination alone, followed by clinical review on the day after vaccination and further monitoring via a diary card for at least a further 24 hours.



Provided there are no safety concerns, a further two volunteers from Group 1 may then be vaccinated, at least 1 hour apart. Following review of the second and third volunteers at the 48-hour timepoint, an internal safety review will be conducted. If no safety concerns are identified, the remaining volunteers in the group will be vaccinated. The staggered enrolment process will be repeated for Group 2 for the first three volunteers. Following this, recruitment to Groups 2 and 3 will occur in parallel.

Volunteers will attend regular follow-up visits after each of the three vaccinations and will self-report adverse events in the post-vaccination period via a diary card. Blood will be taken at regular intervals to assess safety outcomes via laboratory adverse events, as well as the immune response to vaccination. Volunteers will be followed until approximately 8 months from the time of enrolment.

All vaccinations and follow-up visits will be performed at the CCVTM in Oxford.

## **7.4 Study groups**

There will be three study groups (Group 1, Group 2 and Group 3), each comprising 8-10 volunteers. There will be staggered enrolment for Groups 1 and 2 as described below in Section 7.3.1. Any volunteer who is withdrawn or withdraws from the study may be replaced at the discretion of the Investigators.

### **7.4.1 First volunteers**

The first volunteer from Group 1 to receive Pvs25-IMX313/Matrix-M1 will be enrolled and vaccinated alone. Providing there are no safety concerns at 48 hours after the first volunteer has been vaccinated, the second and third volunteers from Group 1 will be vaccinated. Following a further 48 hour period, an internal safety review will be conducted involving the review of participant e-diaries by the Chief Investigator with the Lead Clinician. If at this point there are no safety concerns, the rest of Group 1 may be immunised. This staggered approach will be repeated for the second dose. After at least eight volunteers from Group 1 have received two out of three doses of 10 µg Pvs25-IMX313 in 50 µg Matrix-M1 and had seven days of follow-up, there will be a formal safety review (see below) prior to dose escalation (i.e. recruitment to Groups 2 and 3). The staggered enrolment process will continue for the third vaccination in Group 1 and for Group 2 for the first three volunteers at each of the three doses. Following this, recruitment to Groups 2 and 3 will occur in parallel.

### **7.4.2 Dose escalation**

A minimum of data from eight volunteers recruited to Group 1 will be reviewed prior to dose escalation (i.e. recruitment to Groups 2 or 3). The data to be reviewed will include but is not limited to: physical observations, patient e-diary cards and safety bloods (full blood count, urea and electrolytes, liver function tests). Data up to and including the first seven days following vaccination will be required for each of the eight volunteers prior to dose escalation. E-diary cards will be reviewed on a daily basis for the first eight volunteers recruited to Group 1 for the first seven days following vaccination. A formal safety review will be undertaken by the LSM prior to dose escalation. This would take the form of a safety report incorporating the relevant safety data described above, which would need to be reviewed and approved by the CI and LSM prior to recruitment into Groups 2 and 3.

### 7.4.3 Group 1

Eight to ten volunteers will be recruited into Group 1 (Table 2) and each volunteer will attend for three vaccinations. On the day of enrolment, Pvs25-IMX313 will be administered at a dose of 10 µg in 50 µg Matrix-M1 adjuvant. After approximately 4 weeks, a second dose will be administered, followed by a third and final vaccination approximately 4 weeks later. Second and third vaccinations will be administered at the same dose of both vaccine and adjuvant as at the initial vaccination. Volunteers will be followed until 8 months (approximately) from the time of enrolment.

### 7.4.4 Group 2

Eight to ten volunteers will be recruited into Group 2 (Table 2) and each volunteer will attend for three vaccinations. On the day of enrolment, Pvs25-IMX313 will be administered at a dose of 50 µg in 50 µg Matrix-M1 adjuvant. After approximately 4 weeks, a second dose will be administered, followed by a third and final vaccination approximately 4 weeks later. Second and third vaccinations will be administered at the same dose of both vaccine and adjuvant as at the initial vaccination. Volunteers will be followed until 8 months (approximately) from the time of enrolment.

### 7.4.5 Group 3

Eight to ten volunteers will be recruited into Group 3 (Table 2) and each volunteer will attend for three vaccinations. On the day of enrolment, Pvs25-IMX313 will be administered at a dose of 50 µg in 50 µg Matrix-M1 adjuvant. After approximately 4 weeks, a second dose will be administered, followed by a third and final vaccination approximately 4 weeks later. The second vaccination will be at the same dose as the first vaccination whilst the third vaccination will be administered at a lower dose of Pvs25-IMX313 10 µg in 50 µg Matrix-M1 adjuvant. Volunteers will be followed until 8 months (approximately) from the time of enrolment.

Group	Group size	D0	D28	D56
Group 1	8-10	Pvs25-IMX313 10 µg Matrix-M1 50 µg	Pvs25-IMX313 10 µg Matrix-M1 50 µg	Pvs25-IMX313 10 µg Matrix-M1 50 µg
Group 2	8-10	Pvs25-IMX313 50 µg Matrix-M1 50 µg	Pvs25-IMX313 50 µg Matrix-M1 50 µg	Pvs25-IMX313 50 µg Matrix-M1 50 µg
Group 3	8-10	Pvs25-IMX313 50 µg Matrix-M1 50 µg	Pvs25-IMX313 50 µg Matrix-M1 50 µg	Pvs25-IMX313 10 µg Matrix-M1 50 µg

**Table 2: Vaccination protocol for study groups 1, 2 and 3**

## **7.5 Duration of study**

### **7.5.1 Definition of the start and end of the trial**

The start of the trial is defined as the date of enrolment of the first volunteer. The end of the trial is the date of the last follow-up of the last volunteer.

### **7.5.2 Duration of volunteer participation**

Volunteers will be considered to be enrolled in the trial on the receipt of the first vaccination. Total duration of follow-up will be approximately 8 months from enrolment.

## **7.6 Potential risks for volunteers**

### **7.6.1 Phlebotomy**

The maximum estimated volume of blood drawn (972mL) over the study period should not compromise otherwise healthy volunteers, however, volunteers will be monitored for anaemia. There may be minor bruising, local tenderness, pre-syncopal symptoms or syncope (rarely) associated with venepuncture, which will not be documented as AEs if they occur. The actual total blood volume may vary depending on any requirement for repeat clinical tests, e.g. in the event of a clinically significant abnormal result.

### **7.6.2 Vaccinations**

Potential foreseeable risks from vaccination can be partially predicted from previous studies assessing protein vaccines, administered with the Matrix-M1 adjuvant system, which include local and systemic reactions. Generally, an increase in solicited AEs is seen following administration of investigational vaccines with Matrix-M1 adjuvant, compared to the antigen alone or placebo, however, reactogenicity is transient with the vast majority of adverse events resolving within 2-7 days.

Local adverse events are likely to include: injection site pain, erythema, swelling, itching and warmth. Foreseeable systemic adverse events would include: headache, fatigue, myalgia, arthralgia, malaise, feverishness, fever and nausea. The majority of local and systemic adverse events are foreseen to be mild to moderate in nature, however, it is anticipated that rarely, these may be reported as severe. Of the systemic adverse events reported as severe following receipt of other investigational vaccines administered with Matrix-M1 adjuvant, myalgia is the most common.

As with any vaccine, Guillain-Barré syndrome or immune-mediated reactions that can lead to organ damage including serious allergic reactions may occur, but this should be extremely rare. Serious allergic reactions including anaphylaxis could also occur and for this reason volunteers will be observed for an hour after each vaccination and vaccinated in a clinical area where Advanced Life Support trained physicians, equipment and drugs are immediately available for the management of any SARs.

## **7.7 Potential benefits for volunteers**

Volunteers will not benefit directly from participation in this study. However, it is hoped that the information gained from this study will contribute to the development of a safe and effective *P. vivax* transmission-blocking vaccine. Volunteers will also receive information about their general health status.

## 8 RECRUITMENT AND WITHDRAWAL FOR TRIAL VOLUNTEERS

Volunteers may be recruited by use of an advertisement +/- registration form formally approved by the ethics committee(s) and distributed or posted in the following places:

- In public places, including buses and trains, with the agreement of the owner/proprietor.
- In newspapers or other literature for circulation.
- On a website operated by the Investigators' clinical trials group or with the agreement of the owner or operator (including online recruitment through our website).
- As a post on Twitter, Facebook or other similar account owned and operated by the Investigators' clinical trials group.
- By email distribution to a group or list only with the express agreement of the network administrator or with equivalent authorisation, including those who have already expressed an interest in taking part in any clinical trial at the Oxford Vaccine Centre. This will include a link to the website advertisement.
- On stalls or stands at exhibitions or fairs.
- Via presentations (e.g. presentations at lectures or invited seminars).
- Oxford Vaccine Centre databases: We may contact individuals from databases of groups within the CCVTM (including the Oxford Vaccine Centre database) of previous trial participants who have expressed an interest in receiving information about all future studies for which they may be eligible.

### 8.1 Informed consent

The information sheet will be made available to the volunteer at least 24 hours prior to the screening visit, thus they will have a minimum of 24 hours to consider study participation. At the screening visit, the volunteer will be fully informed of all aspects of the trial, the potential risks and their obligations. The following will be emphasised:

- Participation in the study is entirely voluntary.
- Refusal to participate involves no penalty or loss of medical benefits.
- The volunteer may withdraw from the study at any time.
- The volunteer is free to ask questions at any time to allow him or her to understand the purpose of the study and the procedures involved.
- There is no direct benefit from participating.
- The volunteer's general practitioner (GP) will be contacted to corroborate their medical history. Volunteers will only be enrolled in the study if written information regarding the volunteer's medical history is obtained from the GP.
- The volunteer will be registered on the TOPS database (The Overvolunteering Prevention System; [www.tops.org.uk](http://www.tops.org.uk)).
- With volunteer consent, blood samples will be taken and any leftover samples stored indefinitely for use in other, ethically approved research.

The aims of the study and all tests to be carried out will be explained. The volunteer will be given the opportunity to ask about details of the trial and will then have time to consider whether or not to participate before completing the written consent form. In addition to the consent form, volunteers will be asked to complete an additional separate form regarding consent for the GP to release medical records, a copy of which will be sent to the GP.

The participant must personally sign and date the latest approved version of the Informed Consent form before any trial specific procedures are performed.

Written and verbal versions of the Participant Information and Informed Consent will be presented to the participants detailing no less than: the exact nature of the trial; what it will involve for the participant; the implications and constraints of the protocol; the known side effects and any risks involved in taking part. It will be clearly stated that the participant is free to withdraw from the trial at any time for any reason without prejudice to future care, without affecting their legal rights and with no obligation to give the reason for withdrawal.

The participant will be allowed the opportunity to question the Investigator, their GP or other independent parties to decide whether they will participate in the trial. Written Informed Consent will then be obtained by means of participant dated signature and dated signature of the person who presented and obtained the Informed Consent.

The person who obtained the consent must be suitably qualified and experienced, and have been authorised to do so by the Chief/Principal Investigator. A copy of the signed Informed Consent will be given to the participant. The original signed form will be retained at the trial site.

## **8.2 Inclusion and exclusion criteria**

### **8.2.1 Inclusion criteria**

The volunteer must satisfy all the following criteria to be eligible for the study:

- Healthy adult aged 18 to 45 years.
- Able and willing (in the Investigator's opinion) to comply with all study requirements.
- Willing to allow the Investigators to discuss the volunteer's medical history with their GP.
- Volunteers with the potential to become pregnant only: must practice continuous effective contraception for the duration of the study (see section 10.10).
- Agreement to refrain from blood donation for the duration of the study.
- Able and willing to provide written informed consent to participate in the trial.

### **8.2.2 Exclusion criteria**

The volunteer may not enter the study if any of the following apply:

- History of clinical malaria (any species).
- Travel to a clearly malaria endemic locality during the study period or within the preceding six months.
- Use of immunoglobulins or blood products (e.g., blood transfusion) in the last three months.
- Receipt of any vaccine in the 30 days preceding enrolment, or planned receipt of any other vaccine within 30 days following each study vaccination, with the exception of COVID-19 vaccines, which should not be received between 14 days before to 7 days after any study vaccination.
- Receipt of an investigational product in the 30 days preceding enrolment, or planned receipt during the study period.
- Concurrent involvement in another clinical trial or planned involvement during the study period.
- Prior receipt of an investigational vaccine likely to impact on interpretation of the trial data, as assessed by the Investigator.

- Any confirmed or suspected immunosuppressive or immunodeficient state, including HIV infection; asplenia; recurrent, severe infections and chronic (more than 14 days) immunosuppressant medication within the past 6 months (inhaled and topical steroids are allowed).
- History of allergic disease or reactions likely to be exacerbated by any component of the vaccine.
- Any history of anaphylaxis in reaction to vaccinations.
- Pregnancy, lactation or intention to become pregnant during the study.
- History of cancer (except basal cell carcinoma of the skin and cervical carcinoma in situ).
- History of serious psychiatric condition that may affect participation in the study.
- Any other serious chronic illness requiring hospital specialist supervision.
- Suspected or known current alcohol abuse as defined by an alcohol intake of greater than 25 standard UK units every week.
- Suspected or known injecting drug abuse in the 5 years preceding enrolment.
- Hepatitis B surface antigen (HBsAg) detected in serum.
- Seropositive for hepatitis C virus (antibodies to HCV) at screening (**unless** volunteer has taken part in a prior hepatitis C vaccine study with confirmed negative HCV antibodies prior to participation in that study, and negative HCV ribonucleic acid (RNA) PCR at screening for this study).
- Volunteers unable to be closely followed for social, geographic or psychological reasons.
- Any clinically significant abnormal finding on biochemistry or haematology blood tests, urinalysis or clinical examination. In the event of abnormal test results, confirmatory repeat tests will be requested. Procedures for identifying laboratory values meeting exclusion criteria are shown in SOP VC027.
- Any other significant disease, disorder, or finding which may significantly increase the risk to the volunteer because of participation in the study, affect the ability of the volunteer to participate in the study or impair interpretation of the study data.
- Inability of the study team to contact the volunteer's GP to confirm medical history.

### 8.2.3 Prevention of 'Over Volunteering'

Volunteers will be excluded from the study if they are concurrently involved in another trial. In order to check this, volunteers will be asked to provide their National Insurance or Passport number (if they are not entitled to a NI number) and will be registered on a national database of participants in clinical trials ([www.tops.org.uk](http://www.tops.org.uk)).

### 8.2.4 Vaccination and re-vaccination exclusion criteria

The following events associated with vaccine immunisation constitute absolute contraindications to further administration of vaccine. If any of these events occur during the study, the participant must be withdrawn and followed until resolution of the event, as with any adverse event:

- Anaphylactic reaction following administration of vaccine.
- Pregnancy.

The following adverse events constitute contraindications to administration of vaccine at that point in time; if any one of these adverse events occurs at the time scheduled for vaccination, the participant may be vaccinated at a later date, or withdrawn at the discretion of the Investigator. The participant must be followed until resolution of the event as with any adverse event:

- Acute disease at the time of vaccination. (Acute disease is defined as the presence of a moderate or severe illness with or without fever). All vaccines can be administered to persons with a minor illness such as diarrhoea, mild upper respiratory infection with or without low-grade febrile illness, i.e. temperature of  $\leq 37.5^{\circ}\text{C}/99.5^{\circ}\text{F}$ .
- Temperature of  $>37.5^{\circ}\text{C}$  ( $99.5^{\circ}\text{F}$ ) at the time of vaccination.
- Current COVID-19 infection, defined as ongoing symptoms with positive COVID-19 PCR swab test taken during current illness or positive COVID-19 PCR swab test within preceding 14 days without symptoms. Vaccinations will be delayed by a minimum of 2 weeks from the date of the first positive COVID-19 PCR swab, as long as symptoms are improving or resolved. It will be at the discretion of the Investigator to withdraw a participant if they develop severe COVID-19 disease.

### **8.2.5 Concomitant medications**

As set out by the exclusion criteria, volunteers may not enter the study if they have received any vaccine in the 30 days prior to enrolment or there is planned receipt of any other vaccine within 30 days of each vaccination, any investigational medicinal product within 30 days prior to enrolment or if receipt is planned during the study period, or any chronic (more than 14 days) immunosuppressant medication within 6 months prior to enrolment or if receipt is planned at any time during the study period (inhaled and topical steroids are permitted). One exception is COVID-19 vaccines, which should not be received between 14 days before to 7 days after any study vaccinations.

### **8.3 Withdrawal of volunteers**

In accordance with the principles of the most recent revision of the Declaration of Helsinki (2013) and any other applicable regulations, a volunteer has the right to withdraw from the study at any time and for any reason and is not obliged to give his or her reasons for doing so. In addition, the volunteer may withdraw/be withdrawn from further study procedures at any time in the interests of the volunteer's health and wellbeing, or for any of the following reasons:

- Administrative decision by the Investigator.
- Ineligibility (either arising during the study or retrospectively, having been overlooked at screening).
- Significant protocol deviation.
- Volunteer non-compliance with study requirements.
- An AE, which requires discontinuation of the study involvement or results in inability to continue to comply with study procedures.

The Local Safety Monitor (LSM) may recommend withdrawal of volunteers. The reason for withdrawal from further study procedures will be recorded in the Case Report Form (CRF) where available. For all AEs, appropriate follow-up visits or medical care will be arranged, with the agreement of the volunteer, until the AE has resolved, stabilised or a non-trial related causality has been assigned.

Any volunteer who fails to attend for two or more follow-up visits will be deemed to have withdrawn from the study.

If a volunteer withdraws from the study, blood samples collected before their withdrawal from the trial will be used/stored unless the volunteer specifically requests otherwise. Similarly, all data collected up to the point of withdrawal will be stored, unless they specifically request for it to be

destroyed. Volunteers are free to request that their blood samples be destroyed any time during or after the study.

In all cases of participant withdrawal, excepting those of complete consent withdrawal, long-term safety data collection, including some procedures such as safety bloods, will continue as appropriate if participants have received one or more vaccine doses.

#### **8.4 Pregnancy**

Should a volunteer become pregnant during the trial, she will be followed up as other volunteers and in addition will be followed until pregnancy outcome, with the volunteer's permission. Depending on the timings of pregnancy outcome relative to planned study follow-up timepoints, this may involve additional telephone consultations. We will not routinely perform venepuncture on such volunteers.



## 9. TREATMENT OF TRIAL VOLUNTEERS

This section describes the clinical procedures for evaluating study participants, vaccination and follow-up after vaccination.

### 9.1 Trial sites

Volunteers will be recruited and undergo all visits at the CCVTM, Oxford, this is inclusive of screening, vaccinations and follow-up visits.

### 9.2 Study procedures

Procedures will be performed at the time points indicated in the schedule of events (Table 3). Additional procedures or laboratory tests may be performed, at the discretion of the Investigators if clinically necessary.

#### 9.2.1 Observations

Pulse, blood pressure and temperature will be measured at the time points indicated in the schedule of events (Table 3). In addition, weight and height will be measured at screening.

#### 9.2.2 Blood tests

Blood will be drawn at the time points indicated in the schedule of events (Table 3) and the following laboratory assays performed:

At Oxford University Hospitals NHS Foundation Trust, using NHS standard procedures:

- **Haematology:** Full blood count.
- **Biochemistry:** Sodium, potassium, urea, creatinine, albumin and liver function tests.
- **Diagnostic serology:** HbsAg, HCV antibodies, HIV antibodies.
- **Immunology:** Human Leukocyte Antigen (HLA) typing at the day of enrolment (D0).

At the Jenner Institute research laboratories:

- **Immunology:**
  - Pvs25-specific immunogenicity will be assessed by a variety of immunological assays. These will include *ex vivo* ELISpot assays for interferon gamma and antibody ELISAs for measuring total IgG, isotype and avidity.
  - The functional activity of the vaccine-induced antibodies will be tested using membrane-feeding assays. The functional activity of the purified IgG will be tested against *P. vivax* by DMFA.
  - Other exploratory immunological assays including cytokine analysis, other antibody assays (plasma cell and memory B cell assays), IMX313-specific immunogenicity, human C4b, DNA analysis of genetic polymorphisms potentially relevant to vaccine immunogenicity and gene expression studies, amongst others, may be performed at the discretion of the Investigators. B cells, plasma and/or serum may also be analysed and used to produce human monoclonal antibodies.
  - Samples may also be sent to collaborating laboratories within and outside the UK (including outside of Europe) for other immunological assays as required. This would involve the transfer of serum, plasma or blood cells to these laboratories, but these would remain pseudo-anonymised. Informed consent for this will be obtained from

volunteers. Immunological assays will be conducted according to the procedures established in the test laboratories.

With the volunteers' informed consent, any leftover cells, plasma, serum (or their purified components) will be stored indefinitely in the Oxford Vaccine Centre Biobank for future immunological analysis of malaria-specific or vaccine-related responses. This may include human DNA and RNA analysis. If a participant elects not to permit this, all of that participant's leftover samples will be discarded after the required period of storage to meet Good Clinical Practice (GCP) and regulatory requirements.

### **9.2.3 Urinalysis**

Urine will be tested for the presence of clinically significant proteinuria, glycosuria or haematuria (as defined in Appendix A) at the screening visits. For volunteers with the potential to become pregnant (see section 10.10 for definition), urine will be tested for beta-human chorionic gonadotrophin ( $\beta$ -HCG) at screening, immediately prior to each vaccination, at days 0, 28 and 56 and on day 84.

### **9.2.4 Vaccinations**

Before each vaccination, the ongoing eligibility of the volunteer will be reviewed. The vaccine will be administered as described above in section 5.3. The injection site will be covered with a sterile dressing and the volunteer will stay in the local trial site for observation for 1 hour, in case of immediate adverse events. Observations will be taken 30 minutes after vaccination (+/- 5 minutes) and the sterile dressing removed and injection site inspected. Observations will also be taken at 60 minutes after vaccination (+/- 10 minutes).

An oral thermometer and tape measure will be given to each volunteer, with instructions on use, along with the emergency 24-hour telephone number to contact the on-call study physician if needed.

### **9.2.5 Management of post-vaccination fevers**

Post-vaccination fevers may cause diagnostic uncertainty as concurrent COVID-19 infection is a possibility. If a participant develops a fever within the first 24 hours after vaccination and no other symptoms associated with COVID-19 disease (new onset cough, anosmia or ageusia), then post-vaccination fever is most likely. Participant will be advised to self-isolate until they become afebrile for 24 hours. Participants will be requested to attend their day 1 post-vaccination study visit to allow collection of study samples including safety blood tests. This study visit will be conducted in a side room with study staff wearing appropriate level 1 Personal Protective Equipment (PPE) and participants will be asked to attend the visit by means other than public transport.

If a participant develops a fever post vaccination, which is associated with either new onset cough or anosmia or ageusia, they will be advised to self-isolate as per Public Health England (PHE) guidance and directed to local community based COVID-19 testing. If participants remain febrile more than 48 hours post vaccination, they will be advised to continue self-isolation and directed to local community based COVID-19 testing. Whilst awaiting their COVID-19 PCR test results, participants will be advised not to attend the clinic for study visits.

If a participant tests positive for COVID-19 or whilst awaiting their COVID-19 test result, they will be advised to continue self-isolating as per PHE guidance. Any study visits which are due whilst a participant is self-isolating, should be rescheduled to occur when self-isolation ends, if this falls within the visit window. If a participant remains in self-isolation during the period of the visit

window, then the study visit will be conducted by telephone and no blood tests will be taken. Study visit windows have been increased in order to accommodate these scenarios.

If a participant is self-isolating for a prolonged period post-vaccination (for example because they are a household contact of a suspected or confirmed COVID-19 case) and hence would miss all three initial post vaccination visits, then it will be at the Investigator's discretion to conduct these as physical visits at CCVTM to allow full assessment including blood tests. These study visits would be conducted in a side room with study staff wearing level 1 PPE.

If a participant tests negative for COVID-19, they can stop self-isolating and continue with study visits as planned.

#### **9.2.6 E-diary**

Following each vaccination, volunteers will be asked to complete an e- diary. Volunteers will be asked about foreseeable local and systemic AEs for 7 days (solicited AEs). After this, volunteers will be asked to record any AE daily, for 28 days (unsolicited AEs). E-diary cards will be reviewed with volunteers at each post-vaccination clinic visit.

An electronic PDF copy of the e-diary or hard copy will be issued to participants if there are technical issues with the e-diary or if the participant has internet/accessibility issues.

#### **9.2.7 Photographs**

Photographs of the injection site may be taken in the event of severe pain, redness and/or swelling following vaccination to enable assessment of any improvement/deterioration. Severe is defined as a grading of 3 in any one of the categories detailed in Table 7. Photographs will not include the participant's face.

### **9.3 Study visits**

All clinical reviews and procedures will be undertaken by one of the clinical team. The procedures to be included in each visit are documented in Table 3. Each review is assigned a time point and a window period within which the review will be conducted.

#### **9.3.1 Screening visits**

There will be an initial pre-screening questionnaire that is completed online (<https://www.onlinesurveys.ac.uk>) to assess initial eligibility. Use of this tool has been approved by the University of Oxford. If the prospective participant meets initial eligibility criteria, we will seek consent via email to subsequently contact individuals by telephone. During this pre-screening telephone call with a member of the clinical team to discuss the study, we will provide the opportunity for interested individuals to discuss the study, eligibility criteria and study requirements. If individuals continue to express an interest in taking part in the trial following the pre-screening call and if they meet eligibility criteria, a screening visit will be scheduled.

Screening visits may take place up to 90 days prior to enrolment. Informed consent will be gained at screening. If consent is given, the screening procedures indicated in the schedule of events (Table 3) will be undertaken.

The potential participant's GP will be contacted with the written permission of the participant after screening using the GP screening letter. This will enable the study team to ascertain any significant medical history and act as notification that the participant has volunteered for the study.

During the screening the volunteers will be asked to provide their National Insurance or passport number so that this can be entered on to a national database which helps prevent volunteers from participating in more than one clinical trial simultaneously or over-volunteering for clinical trials ([www.tops.org.uk](http://www.tops.org.uk)).

Where more than 90 days has lapsed between the initial screening visit and date of enrolment, a re-screening visit will be conducted to ascertain if there have been any changes in the medical history or physical examination findings. Urinalysis, biochemistry and haematology blood tests will be repeated. Other blood tests will not be repeated routinely. Where a reply from the potential participant's GP has already been received, the GP will not be re-contacted unless there is any need to obtain further information where appropriate (e.g. regarding a new medical event or finding) and at the discretion of the Investigator.

Hepatitis B, Hepatitis C and HIV status will be checked via blood tests at the screening visit. Some individuals may test positive for Hepatitis C virus due to their previous involvement in a Hepatitis C vaccine study. If this applies to an individual and they wish to take part in our study, with their consent, we will contact the team responsible for the Hepatitis C vaccine study to check the participant's Hepatitis C status prior to enrolment in this malaria vaccine study. A copy of the consent will be held by both study teams.

### **9.3.2 Enrolment and first vaccination (V1) with Pvs25-IMX313 in Matrix-M1 adjuvant (all groups)**

The eligibility of the volunteer will be reviewed at the end of the screening visit and again when all results from the screening visit have been considered. If eligible, a day 0 visit will be scheduled for the volunteer to receive the first dose of vaccine and be enrolled in the trial.

At the day 0 visit, any new medical issues or symptoms that have arisen will be assessed. Physical observations, urinary  $\beta$ -hCG test in volunteers with the potential to become pregnant and venepuncture for immunology and safety bloods will be undertaken according to Table 3. The inclusion and exclusion criteria for the study will be reviewed. If the volunteer remains eligible and there are no contraindications to vaccination, the Pvs25-IMX313 vaccine, formulated in Matrix-M1 adjuvant will be administered according to the doses described in Table 3 and as described in Section 5.3. The visit will be carried out as described in above Section 9.2.4.

### **9.3.3 Reviews post-vaccination on days 1, 7 and 14 (all groups)**

On subsequent visits, the volunteers will be assessed for local and systemic AEs, using the diary card, interim history, physical examination and blood tests at the time points indicated in the schedule of events (Table 3). Blood will also be taken for exploratory immunology analyses.

Volunteers will be asked to record all AEs via the diary card. E-diary cards will be reviewed with volunteers at the clinic visits on days 1 and 7. Volunteers will be asked directly about foreseeable local and systemic AEs for 7 days (solicited AEs). They will also be asked daily about any new symptoms from day 7 until day 28 via the diary but will not be asked directly about foreseeable symptoms. E-diary cards will be reviewed for details of solicited and unsolicited AEs for 28 days after each vaccination, and any new or previously undocumented medical issues or symptoms that have arisen will be assessed. Physical observations and venepuncture for immunology and safety bloods will be undertaken according to Table 3. At any post-vaccination visit, where valid written, informed consent is in place, photographs may be taken for clinical comparison. This will enable qualitative as well as quantitative assessment of redness and swelling at the injection site. Confidentiality will be maintained as described in Section 13.5.

### **9.3.4 Second vaccination (V2) with Pvs25-IMX313 in Matrix-M1 adjuvant on day 28 (all groups)**

This visit will include a follow-up visit for the first vaccination and administration of the second vaccine. Any new medical issues or symptoms that have arisen will be assessed. Physical observations, urinary  $\beta$ -hCG test in volunteers with the potential to become pregnant and venepuncture for immunology and safety bloods will be undertaken according to Table 3. The inclusion and exclusion criteria for the study will be reviewed. If the volunteer remains eligible and there are no contraindications to vaccination, the Pvs25-IMX313 vaccine, formulated in Matrix-M1 adjuvant will be administered intramuscularly in the opposite arm to that used for the first vaccination and as described in sections 5.3 and 9.2.4. Dosing will be determined by group allocation (see Table 3).

### **9.3.5 Reviews post-vaccination on days 29, 35 and 42 (all groups)**

On subsequent visits, the volunteers will be assessed for local and systemic AEs, using the diary card, interim history, physical examination and blood tests at the time points indicated in the schedule of events (Table 3). Blood will also be taken for exploratory immunology analysis.

Volunteers will be asked to record all AEs via the diary card. E-diary cards will be reviewed with volunteers at the clinic visits on days 29 and 35. Volunteers will be asked directly about foreseeable local and systemic AEs for 7 days (solicited AEs). They will also be asked daily about any new symptoms from day 35 until day 56 via the diary but will not be asked directly about foreseeable symptoms. E-diary cards will be reviewed for details of solicited and unsolicited AEs for 28 days after each vaccination, and any new or undocumented medical issues or symptoms that have arisen will be assessed. Physical observations and venepuncture for immunology and safety bloods will be undertaken according to Table 3. At any post-vaccination visit, where valid written, informed consent is in place, photographs may be taken for clinical comparison. Confidentiality will be maintained as described in Section 13.5.

### **9.3.6 Third vaccination (V3) with Pvs25-IMX313 in Matrix-M1 adjuvant on day 56 (all groups)**

This visit will include a follow-up visit for the second vaccination and administration of the third vaccine. Any new medical issues or symptoms that have arisen will be assessed. Physical observations, urinary  $\beta$ -hCG test in volunteers with the potential to become pregnant and venepuncture for immunology and safety bloods will be undertaken according to Table 3. The inclusion and exclusion criteria for the study will be reviewed. If the volunteer remains eligible and there are no contraindications to vaccination, the Pvs25-IMX313 vaccine, formulated in Matrix-M1 adjuvant will be administered intramuscularly in the opposite arm to that used for the second vaccination and as described in sections 5.3 and 9.2.4. Dosing will be determined by group allocation (see Table 2).

### **9.3.7 Reviews post-vaccination on days 57, 63, 70 and 84**

On subsequent visits, the volunteers will be assessed for local and systemic adverse events, using a diary card, interim history, physical examination and blood tests at the time points indicated in the schedule of attendances (Table 3). Blood will also be taken for exploratory immunology analysis.

Volunteers will be asked to record all AEs via the diary card and at visits on days 57 and 63, during which e-diary cards will be reviewed with volunteers. Volunteers will be asked directly about foreseeable local and systemic AEs for 7 days (solicited AEs). Volunteers will be asked to continue to record any new symptoms from day 63 until day 84, on a daily basis via the diary but will not be asked directly about foreseeable symptoms. E-diary cards will be reviewed for details of solicited

and unsolicited AEs for 28 days after each vaccination, and any new or undocumented medical issues or symptoms that have arisen will be assessed. Physical observations, procedures (including a urinary pregnancy test at D84) and venepuncture for immunology and safety bloods will be undertaken according to Table 3. At any post-vaccination visit, where valid written, informed consent is in place, photographs may be taken for clinical comparison. Confidentiality will be maintained as described in Section 13.5.

#### **9.3.8 Long-term follow up post-vaccination on days 140 and 240**

On days 140 and 240, volunteers will be assessed for serious adverse events, by interim history, and physical examination, as deemed necessary by the Investigator. Blood tests will be performed as indicated in the schedule of attendances for these timepoints (Table 3). Blood will also be taken for exploratory immunology analysis. At any post-vaccination visit, where valid written, informed consent is in place, photographs may be taken for clinical comparison. Confidentiality will be maintained as described in Section 13.5.

	S	V1				V2				V3						
Attendance number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Timeline (days)		0	1	7	14	28	29	35	42	56	57	63	70	84	140	240
Window (days)	-90		±1	±2	-2/+4	-7/+14	±1	±2	-2/+4	-7/+14	±1	±2	-2/+4	-7/+14	±14	±14
Inclusion/Exclusion criteria	X	X														
Informed consent	X	X														
Physical observations*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Medical history/ examination	X	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Photographs		(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Urinalysis	X															
Urine β-hCG**	X	X				X				X				X		
Review contraindications		X				X				X						
Review AEs & medications			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Vaccination		X				X				X						
Diary card issued		X				X				X						
Diary card collected						X				X				X		
Immunology plasma (mL)		30	10	10	30	80	10	60	30	30	10	60	30	80	30	30
Immunology serum (mL)		40			40	40			40	40			40	40	40	40
RNA preservation (mL)		3	3			3	3			3	3					
Haematology (mL)#	2	2		2	2	2		2	2	2		2	2	2		
Biochemistry (mL) ##	3	3		3	3	3		3	3	3		3	3	3		
HLA typing (mL)		4														
HIV, HBV, HCV serology (mL)	5															
Total Blood Volume (mL)	10	82	13	15	75	128	13	65	75	78	13	65	75	125	70	70
Cumulative blood volume (mL)	10	92	105	120	195	323	336	401	476	554	567	632	707	832	902	972 <sup>s</sup>

**Table 3: Schedule of events**

**S** = screening visit; **V** = vaccination; **(X)** = If considered necessary, emphasising any acute complaints. \*Physical observations will include blood pressure, heart rate and temperature, plus height and weight at screening only. \*\*For volunteers with the potential to become pregnant. # Haematology will comprise full blood count. ## Biochemistry will include sodium, potassium, urea, creatinine, albumin, liver function tests. \$ Cumulative blood volume if blood taken as per schedule and excluding any repeat safety blood tests that may be necessary.

## **10 ASSESSMENT OF SAFETY**

Safety will be assessed by the frequency, incidence and nature of AEs and SAEs arising during the study. The safety profile will be assessed on an ongoing basis by the Investigators during the safety reporting window for each participant (from provision of consent to their last study visit). The CI and relevant Investigators (as per the trial delegation log) will also review safety issues and SAEs as they arise.

### **10.1 Definitions**

#### **10.1.1 Adverse Event (AE)**

An AE is any untoward medical occurrence in a volunteer, which may occur during or after administration of an Investigational Medicinal Product (IMP) and does not necessarily have a causal relationship with the intervention. An AE can therefore be any unfavourable and unintended sign (including an abnormal laboratory finding), symptom or disease temporally associated with the study intervention, whether or not considered related to the study intervention.

Each participant-reported AE will be graded by the participant according to the table for grading severity of adverse events (see Table 5). Severity gradings may be reviewed and discussed with the participants at the clinic visits.

#### **10.1.2 Adverse Reaction (AR)**

An AR is any untoward or unintended response to an IMP. This means that a causal relationship between the IMP and an AE is at least a reasonable possibility, i.e. the relationship cannot be ruled out. All cases judged by the reporting medical Investigator as having a reasonable suspected causal relationship to an IMP (i.e. possibly, probably or definitely related to an IMP) will qualify as ARs.

#### **10.1.3 Serious Adverse Event (SAE)**

An SAE is an AE that results in any of the following outcomes, whether or not considered related to the study intervention:

- Death.
- Life-threatening event (i.e. the volunteer was, in the view of the Investigator, at immediate risk of death from the event that occurred). This does not include an AE that, if it occurred in a more severe form, might have caused death.
- Persistent or significant disability or incapacity (i.e. substantial disruption of one's ability to carry out normal life functions).
- Hospitalisation or prolongation of hospitalisation, regardless of length of stay, even if it is a precautionary measure for continued observation. Hospitalisation (including inpatient or outpatient hospitalisation for an elective procedure) for a pre-existing condition that has not worsened unexpectedly does not constitute an SAE.
- An important medical event (that may not cause death, be life-threatening, or require hospitalisation) that may, based upon appropriate medical judgment, jeopardise the volunteer and/or require medical or surgical intervention to prevent one of the outcomes listed above. Examples of such medical events include allergic reaction requiring intensive treatment in an emergency room or clinic, blood dyscrasias, or convulsions that do not result in inpatient hospitalisation.



- Congenital anomaly or birth defect.

#### 10.1.4 Serious Adverse Reaction (SAR)

An AE (expected or unexpected) that is both serious and, in the opinion of the reporting Investigator or Sponsors, believed to be possibly, probably or definitely due to an IMP or any other study treatments, based on the information provided.

#### 10.1.5 Suspected Unexpected Serious Adverse Reaction (SUSAR)

All SAEs at least possibly related to Pvs25-IMX313/Matrix-M1 will be considered unexpected and be reported as SUSARs.

#### 10.1.6 Foreseeable Adverse Reactions

The foreseeable ARs following vaccination with Pvs25-IMX313 in Matrix-M1 adjuvant are: injection site pain, erythema, warmth, swelling, pruritus, myalgia, arthralgia, headache, fatigue, fever, feverishness, malaise and nausea. These AEs will be listed as 'solicited AEs' providing they occur within 7 days of the day of vaccination. 'Unsolicited AEs' are AEs other than the foreseeable ARs occurring within the first 7 days, or any AEs occurring after the first 7 days after vaccination.

### 10.2 Causality Assessment

For every unsolicited AE, an assessment of the relationship of the event to the administration of the vaccine will be undertaken by the CI or the CI-delegated clinician at the coordinating site (Oxford). An intervention-related AE refers to an AE for which there is a possible, probable or definite relationship to administration of a vaccine. An interpretation of the causal relationship of the intervention to the AE in question will be made, based on the type of event; the relationship of the event to the time of vaccine administration; and the known biology of the vaccine therapy (Table 4).

Causality assessment will take place during planned safety reviews, interim analyses (e.g. if a holding or stopping rule is activated) and at the final safety analysis, except for SAEs, for which causality should be assigned by the reporting Investigator.

0	<b>No Relationship</b>	No temporal relationship to study product <b>and</b> Alternate aetiology (clinical state, environmental or other interventions); <b>and</b> Does not follow known pattern of response to study product
1	<b>Unlikely</b>	Unlikely temporal relationship to study product <b>and</b> Alternate aetiology likely (clinical state, environmental or other interventions) <b>and</b> Does not follow known typical or plausible pattern of response to study product.

2	<b>Possible</b>	Reasonable temporal relationship to study product; <b>or</b> Event not readily produced by clinical state, environmental or other interventions; <b>or</b> Similar pattern of response to that seen with other vaccines
3	<b>Probable</b>	Reasonable temporal relationship to study product; <b>and</b> Event not readily produced by clinical state, environment, or other interventions <b>or</b> Known pattern of response seen with other vaccines
4	<b>Definite</b>	Reasonable temporal relationship to study product; <b>and</b> Event not readily produced by clinical state, environment, or other interventions; <b>and</b> Known pattern of response seen with other vaccines

**Table 4:** Guidelines for assessing the relationship of vaccine administration to an AE.

### 10.3 Reporting Procedures for all AEs

All AEs occurring in the 28 days following each vaccination observed by the Investigator or reported by the volunteer, whether or not attributed to the study vaccine, will be recorded. Recording and reporting of all AEs will take place as detailed in SOP VC027. We will not record bruising due to blood-taking or cannulation. All AEs that result in a volunteer's withdrawal from the study will be followed up until a satisfactory resolution occurs, or until a non-study related causality is assigned (if the volunteer consents to this). SAEs will be collected throughout the entire trial period. For each participant, this means the safety reporting window per participant (from provision of study consent to final follow-up visit)

Each AE will be graded by the participant according to the table for grading severity of AEs (see Table 5). Severity gradings may be reviewed and discussed with the participants at the clinic visits. Volunteers will be instructed on how to self-assess the severity of these AEs. There will also be space on the diary card to self-document unsolicited AEs, and whether medication was taken to relieve the symptoms.

The severity of clinical AEs will be assessed by the Investigators according to the scales in Tables 5-7. Severity grading for laboratory AEs are dependent on the Oxford University Hospitals laboratory's reference and will be graded according to the scales in the site-specific table that can be found in the Trial Master File. These ranges will be based on FDA guidance relative to local laboratory reference ranges [<https://www.fda.gov/media/73679/download>].

Grade	Severity
GRADE 0	None
GRADE 1	Mild: Transient or mild discomfort (< 48 hours); no medical intervention/therapy required
GRADE 2	Moderate: Mild to moderate limitation in activity – some assistance may be needed; no or minimal medical intervention/therapy required
GRADE 3	Severe: Marked limitation in activity, some assistance usually required; may require medical intervention/therapy

**Table 5: Severity grading criteria for AEs.**

Physical Observations	Grade 1	Grade 2	Grade 3
Tachycardia – beats per min*	101-115	116-130	>130
Hypotension (systolic) mm Hg	85-89	80-84	<80
Hypertension (systolic) mm Hg**	141-159	160-179	≥180
Hypertension (diastolic) mm Hg**	91-99	100-109	≥110
Fever °C	37.6 – 38.0	38.1-39.0	>39.0

**Table 6: Severity grading criteria for clinically significant abnormal physical observations.** All observations should be measured at rest. \*Only applies when resting heart rate is between 60 and 100 beats per minute. Use clinical judgement when characterising bradycardia in some healthy participant populations (e.g. conditioned athletes). \*\*Systolic or diastolic hypertension may only be confirmed as clinically significant (and therefore an AE) if persistently present when observations are repeated (i.e. isolated measurements of hypertension are not clinically significant).

Adverse Event	Grade	Intensity
Pain at injection site	1	Pain that is easily tolerated
	2	Pain that interferes with daily activity
	3	Pain that prevents daily activity

Erythema at injection site	1	>3 - ≤50 mm
	2	>50 - ≤100 mm
	3	>100 mm
Swelling at injection site*	1	>3 - ≤20 mm
	2	>20 - ≤50 mm
	3	>50 mm

**Table 7:** Severity grading criteria for local adverse events. \*Erythema or swelling ≤3mm is an expected consequence of skin puncture and will therefore not be considered an adverse event.

#### 10.4 Reporting Procedures for SAEs

This will be conducted in accordance with the SOP OVC005 Safety Reporting. In order to comply with current regulations on SAE reporting to regulatory authorities, the event will be documented accurately and notification deadlines respected. SAEs will be reported on the SAE forms to members of the study team immediately after the Investigators become aware of their occurrence, as described in SOP OVC005. Copies of all reports will be forwarded for review to the CI as the Sponsor's representatives) within 24 hours of the Investigator being aware of the suspected SAE. The Local Safety Monitor (LSM) will be notified of SAEs which are deemed possibly, probably or definitely related to study interventions; the LSM will be notified immediately (within 24 hours) of the Investigators' being aware of their occurrence. SAEs will not normally be reported immediately to the REC unless there is a clinically important increase in occurrence rate, an unexpected outcome, or a new event that is likely to affect safety of trial volunteers, at the discretion of the CI and/or LSM. In addition to the reporting above, the Investigator shall include all SAEs in the annual Development Safety Update Report (DSUR) report.

##### 10.4.1 Reporting Procedures for SUSARs

The CI will report all SUSARs to the MHRA and REC within required timelines (15 days for all SUSARs, unless life-threatening or fatal). Fatal and life-threatening SUSARs will be reported to the MHRA and REC no later than 7 calendar days after the Sponsor or delegate is first aware of the reaction. Any additional relevant information will be reported within 8 calendar days of the initial report. All other SUSARs will be reported within 15 calendar days of awareness. The CI will also inform all Investigators concerned of relevant information about SUSARs that could adversely affect the safety of participants.

All SUSARs and deaths occurring during the study will be reported to the Sponsor. For all deaths, available autopsy reports and relevant medical reports will be made available for reporting to the relevant authorities.

#### 10.5 Development Safety Update Report

The CI will submit (in addition to the expedited reporting above) DSURs once a year throughout the clinical trial, or on request, to the Competent Authority (MHRA in the UK, Ethics Committee, HRA, Host NHS Trust and Sponsor).

## 10.6 AEs of Special Interest

AEs of special interest will be reported as SAEs. These are:

- Severe hypersensitivity reactions (e.g. anaphylaxis)
- Any new, suspected autoimmune or chronic inflammatory disease

## 10.7 Procedures to be followed in the event of abnormal findings

Eligibility for enrolment in the trial in terms of laboratory findings will be assessed as detailed in SOP VC027. Abnormal clinical findings from medical history, examination or blood tests will be assessed as to their clinical significance throughout the trial. Laboratory AEs will be assessed using the site-specific tables in the Trial Master File (TMF). If a test is deemed clinically significant, it may be repeated, to ensure it is not a single occurrence. If a test remains clinically significant, the volunteer will be informed and appropriate medical care arranged as appropriate and with the permission of the volunteer. Decisions to exclude the volunteer from enrolling in the trial or to withdraw a volunteer from the trial will be at the discretion of the Investigator.

## 10.8 Local Safety Monitor

The LSM will be appointed to provide real-time safety oversight. The LSM will review SAEs deemed possibly, probably or definitely related to study interventions. The LSM will be notified within 24 hours of the Investigators' being aware of their occurrence. The LSM has the power to terminate the study if deemed necessary following a study intervention-related SAE. At the time of writing, the LSM is Prof Brian Angus, a Clinical Tutor in Medicine, Honorary Consultant Physician and Director, Centre for Tropical Medicine at the University of Oxford. All correspondence between the Investigator and the LSM will be conveyed by the Investigator to the trial Sponsor on their request.

The LSM may be contacted for advice and independent review by the Investigator or trial Sponsor in the following situations:

- Following any SAE deemed to be possibly, probably, or definitely related to a study intervention
- Any other situation where the Investigator or trial sponsor feels independent advice or review is important.

The study can be put on hold upon advice of the LSM, CI, study sponsor or Ethical Committee(s), for any single event or combination of multiple events which, in their professional opinion, jeopardise the safety of the participants or the reliability of the data. If the study is placed on hold it may only be restarted following discussion with and approval from the LSM, the ethics committee(s), the trial Sponsor, the MHRA and CI.

## 10.9 Safety Stopping/Holding Rules

Safety holding rules have been developed considering the fact that this is a first-in-human study.

### 10.9.1 Group holding rules (applies to Groups 1 and 2/3)

If a holding rule is activated, then further vaccinations in the group (Group 1 and/or Group 2/3) will not occur until an internal safety review has been conducted and it is deemed appropriate to restart dosing. Note that as Groups 2 and 3 will be recruited in parallel, if a group holding rule is activated for one of the two groups, then further vaccinations in both groups would go on hold. The regulatory authority must be informed of the hold via substantial amendment and a request

to restart dosing with pertinent data must be submitted as a further, subsequent substantial amendment. The internal safety review will consider:

- The relationship of the AE or SAE to the vaccine.
- The relationship of the AE or SAE to the vaccine dose, or other possible causes of the event.
- If appropriate, additional screening or laboratory testing for other volunteers to identify those who may develop similar symptoms, and alterations to the current Participant Information Sheet (PIS) are discussed.
- New, relevant safety information from ongoing research programmes on the various components of the vaccine (i.e. the Matrix-M1 adjuvant).

The local ethics committee and adjuvant system manufacturers (Novavax) will also be notified if a holding rule is activated or released to ensure that each Party is obliged to comply with the performance and activities related to the clinical trial (there is a confidential Safety Data Exchange Agreement, SDEA, in place). All vaccinated volunteers will be followed for safety until resolution or stabilisation (if determined to be chronic sequelae) of their AEs. Novavax will be provided with SAE and pregnancy reports and any safety concerns causing a suspension as per the SDEA between Oxford and Novavax

The group holding rules are as follows:

- **Solicited local AEs:**
  - If more than 25% of doses of a vaccine are followed by the same Grade 3 solicited local AE beginning within 2 days after vaccination (day of vaccination and one subsequent day) and persisting at Grade 3 for > 72 hrs.
- **Solicited systemic AEs:**
  - If more than 25% of doses of a vaccine are followed by the same Grade 3 solicited systemic AE beginning within 2 days after vaccination (day of vaccination and one subsequent day) and persisting at Grade 3 for > 48 hrs.
- **Unsolicited AEs:**
  - If more than 25% of volunteers develop the same Grade 3 unsolicited AE (including the same laboratory AE) that is considered possibly, probably or definitely related to vaccination and persists at Grade 3 for > 48 hrs.
- **A serious AE considered possibly, probably or definitely related to vaccination occurs**

#### 10.9.2 Individual stopping rules

In addition to the above stated group holding rules, stopping rules for individual volunteers will apply (i.e., indications to withdraw individuals from further vaccinations).

- **Local reactions:** Injection site ulceration, abscess or necrosis.
- **Laboratory AEs:**

- The volunteer develops a Grade 3 laboratory AE considered possibly, probably or definitely related within 7 days after vaccination and persisting continuously at Grade 3 for >72hrs.
- **Solicited systemic AEs:**
  - The volunteer develops a Grade 3 systemic solicited AE considered possibly, probably or definitely related within 2 days after vaccination (day of vaccination and one subsequent day) and persisting continuously at Grade 3 for >72hrs.
- **Unsolicited AEs:**
  - The volunteer has a Grade 3 AE, considered possibly, probably or definitely related to vaccination, persisting continuously at Grade 3 for >72hrs.
  - The volunteer has an acute allergic reaction or anaphylactic shock following the administration of the vaccine investigational product.
- **A serious AE considered possibly, probably or definitely related to vaccination occurs**

In addition to these pre-defined criteria, the study can be put on hold upon advice of the LSM, CI, study sponsor, regulatory authority or REC, for any single event or combination of events which, in their professional opinion, jeopardise the safety of the volunteers or the reliability of the data.

#### **10.10 Contraception and pregnancy**

Volunteers with the potential to become pregnant are defined as those who are fertile and able to become pregnant following menarche until becoming post-menopausal, unless permanently sterile. A post-menopausal state is defined as no menstruation for 12 months without a known cause.

Volunteers with the potential to become pregnant are required to use an effective form of contraception during the course of the study as this is a Phase I, first-in-human, study and there is currently no information about the effect of this vaccine on a foetus.

Acceptable forms of contraception for volunteers of child-bearing potential are:

- Established use of oral, injected or implanted hormonal methods of contraception.
- Placement of an intrauterine device or intrauterine system.
- Male sterilization: if the vasectomised partner is the sole partner for the participant.
- True abstinence from sex with sperm-producing partners, when this is in line with the preferred and usual lifestyle of the participant (periodic abstinence and withdrawal are not acceptable methods of contraception).

Pregnancy, lactation or intention to become pregnant during the study is an exclusion criteria.

## **11 STATISTICS**

### **11.1 Sample size**

This is an observational and descriptive safety study, where healthy adult volunteers living in the UK will be vaccinated with Pvs25-IMX313, in formulation with the Matrix-M1 adjuvant. Up to a total of 30 volunteers across three equally divided groups will be vaccinated. Each volunteer will receive three doses of Pvs25-IMX313, formulated in 50 µg Matrix-M1, on days 0, 28 and 56 (see Table 2 for exact dosing regimen depending on group allocation). This sample size should allow estimation and comparison of the frequency and magnitude of the outcome measures, at and between the three different dosing regimens. As this is the first study involving the Pvs25-IMX313 in Matrix-M1 vaccine, there is no available data to enable more precise modelling/power calculations. However, it is considered that eight to ten volunteers in each group will be sufficient to enable detection of statistically significant differences in the primary and secondary outcome measures (see Section 6) between the groups.



## **12 QUALITY CONTROL AND QUALITY ASSURANCE PROCEDURES**

### **12.1 Investigator procedures**

Approved site-specific SOPs will be used at all clinical and laboratory sites.

### **12.2 Monitoring**

Monitoring will be performed by Appledown external monitors using established procedures, according to the principles of Good Clinical Practice (GCP). Following written SOPs, the monitors will verify that the clinical trial is conducted and data are generated, documented and reported in compliance with the protocol and GCP. The site will provide direct access to all trial-related source data/documents and reports for the purpose of auditing by the Sponsor and inspection by local and regulatory authorities.

### **12.3 Modification to protocol**

No amendments to this protocol will be made without consultation with, and the agreement of, the Sponsor. Any amendments to the trial that become necessary during the course of the trial must be discussed by the Investigator and Sponsor concurrently. If agreement is reached concerning the need for an amendment, it will be produced in writing by the CI and will be made a formal part of the protocol following ethical and regulatory approval, as applicable.

An administrative change to the protocol is one that modifies administrative and logistical aspects of a protocol but does not affect the participant's safety, the objectives of the trial and/or its progress. An administrative change may not require UK ethical committee approval; however, the REC will be notified in the event of any such change.

The Investigator is responsible for ensuring that changes to an approved trial, during the period for which ethical committee(s) approval has already been given, are not initiated without review and approval from the ethics committee(s) and regulatory authorities except to eliminate apparent immediate hazards to the participant (Urgent Safety Measures only). Protocol adherence is a fundamental part of the conduct of a clinical study. Changes to the approved protocol need prior approval unless for urgent safety reasons. Investigators must not request a protocol waiver to enter a patient who does not satisfy the selection criteria.

### **12.4 Protocol deviation**

Any deviations from the protocol will be documented in a protocol deviation form and filed in the TMF.

### **12.5 Audit & inspection**

The Quality Assurance manager performs systems-based internal audits to check that trials are being conducted, data recorded, analysed and accurately reported according to study protocols, departmental SOPs and in compliance with GCP. The audit schedule includes laboratory activities. The internal audits will supplement the independent monitoring process and will review processes not covered by the independent monitor.

The Sponsor, trial site, ethical committee(s), and authorised individuals may carry out audit to ensure compliance with the protocol, GCP and appropriate regulations. GCP inspections may also be undertaken by the regulatory authority to ensure compliance with protocol and national regulations. The Sponsor will assist in any inspections.

## **12.6 Serious breaches**

The Medicines for Human Use (Clinical Trials) Regulations contain a requirement for the notification of "serious breaches" to the MHRA within 7 days of the Sponsor becoming aware of the breach.

A serious breach is defined as "A breach of GCP or the trial protocol which is likely to effect to a significant degree –

- (a) the safety or physical or mental integrity of the participants of the trial; or
- (b) the scientific value of the trial.

In the event that a serious breach is suspected the Sponsor must be contacted within 1 working day. In collaboration with the CI the serious breach will be reviewed by the Sponsor and, if appropriate, the Sponsor will report it to the REC, regulatory authority and the relevant NHS host organisation within seven calendar days.

## **12.7 Publication policy**

The Investigators will be involved in reviewing drafts of the manuscripts, abstracts, press releases and any other publications arising from the study. Authorship will be determined in accordance with the International Committee of Medical Journal Editors guidelines and other contributors will be acknowledged.

## **12.8 Intellectual Property**

Ownership of intellectual property generated by employees of the University vests in the University. The protection and exploitation of any new intellectual property is managed by the University's technology transfer office, Oxford University Innovation.

## **13 ETHICS**

### **13.1 Declaration of Helsinki**

The Investigator will ensure that this study is conducted according to the principles of the current revision of the Declaration of Helsinki 2008.

### **13.2 Good Clinical Practice**

The Investigator will ensure that this study is conducted in full conformity to the Medicines for Human Use (Clinical Trials) Regulations 2004 (SI 2004 No. 1031) and its amendments and with the guidelines for GCP (CPMP/ICH/135/95) July 1996.

### **13.3 Approvals**

Following Sponsor approval, a copy of the protocol, proposed informed consent form, other written volunteer information and the proposed advertising material will be submitted to an appropriate REC and the MHRA for written approval. The Investigator will submit and, where necessary, obtain approval from the REC and the MHRA for all subsequent amendments to the protocol and associated trial documents. A non-substantial amendment does not require REC approval; however, the REC will be notified in the event of any such change. The Investigator will notify all deviations from the protocol or SAEs occurring at the site to the Sponsor and will notify the REC(s) and regulatory authorities of these if necessary and in accordance with procedures.

### **13.4 Reporting**

The CI shall submit once a year throughout the study, or on request, an Annual Progress Report to the REC, HRA (where required) and Sponsor. In addition, an End of Trial notification and final report will be submitted to the MHRA, the REC, host organisation and Sponsor.

### **13.5 Volunteer confidentiality**

The research data will be pseudoanonymised; participant data will be identified by a unique study number in the CRF and database. Separate confidential files containing identifiable information and links to the study number will be stored in secured locations. These secured locations are either physical premises or web servers owned by the University of Oxford or in the case of the eCRF on the OpenClinica database. The OpenClinica database has undergone the Third Party Security Assessment process and been officially approved as a processor of data for which the University of Oxford is the controller. Only the Sponsor, Investigators, the clinical monitor, the ethical committee(s) and the regulatory authorities will have access to the records.

Photographs taken (if required, with the volunteer's written, informed consent) will not include the volunteer's face and will be identified by the volunteer's trial specific identification number only. Once developed, photographs will be stored as confidential records, as above. This material may be shown to other professional staff, used for educational purposes, or included in a scientific publication.

## **14 DATA HANDLING AND RECORD KEEPING**

### **14.1 Data handling**

The CI will be the data custodian with responsibility for delegating the receiving, entering, cleaning, querying, analysing and storing all data that accrues from the study. Data will be entered into the volunteers' CRFs in a paper and/or electronic format (using the OpenClinica™ database). Electronic data will be stored on secure servers which are outsourced by OpenClinica™. OpenClinica™ meets FDA part 11B standards and is a system approved by the University of Oxford. This includes safety data, laboratory data and outcome data. Data are entered in a web browser on personal computers and then transferred to the OpenClinica Database by encrypted (https) transfer. Safety data will also be collected through an electronic diary, which is stored on a third party server (see Section 13.5).

### **14.2 Record keeping**

The Investigators will maintain and retain appropriate medical and research records and essential documents for this trial in compliance with GCP and regulatory and institutional requirements for the protection of confidentiality of volunteers. The CI, co-investigators, clinical research nurses and authorised personnel will have access to records. The Investigators will permit authorised representatives of the Sponsor, ethical committee(s), regulatory agencies, and the monitors to examine (and when required by applicable law, to copy) clinical records for the purposes of quality assurance reviews, audits and evaluation of the study safety and progress.

### **14.3 Source data and electronic case report forms (eCRFs)**

All protocol-required information will be collected in the electronic diaries and eCRFs designed by the Investigator. All source documents will be filed in the participants' notes. Source documents are original documents, data, and records from which the volunteer's eCRF data are obtained. For this study these will include, but are not limited to: the volunteer consent form, blood results, GP response letters, laboratory records and correspondence. In the majority of cases, electronic diaries and eCRF entries will be considered source data as these are the site of the original recording (i.e. there is no other written or electronic record of data). In this study this will include, but is not limited to: medical history, medication records, vital signs, physical examination records, urinalysis results, blood results, AE data and details of study interventions. All source data and volunteer CRFs will be stored securely.

### **14.4 Data protection**

The trial will comply with the UK General Data Protection Regulation (UK GDPR) and Data Protection Act 2018. The study protocol, documentation, data and all other information generated will be held in strictest confidence. No information concerning the study or the data will be released to any unauthorised third party, without prior written approval of the Sponsor.

### **14.5 Storage and use of data**

The University of Oxford will keep identifiable information from participants collected during the study for a maximum of 5 years after the study has finished. This will be limited to the minimum personal data necessary. In addition, we will securely store the anonymised research data and any research documents with personal information, such as consent forms, for a maximum of 5 years after the end of the study. The need to store this information for longer, in relation to licensing of the vaccine will be reviewed every 5 years. Once the study has been completed, all documents

would be archived in a secure facility. Files will be confidentially destroyed if storage is no longer required. For effective vaccines that may be licensed, secure storage of research data may be required for at least 15 years after the end of the study, subject to adjustments in clinical trials regulations. Financial information will be stored for seven years in line with University of Oxford financial policy.

Where specific written consent is provided, personal details may be used to contact participants about future related research. These details and clinical information will be held separately. Note that the informed consent form from this study will be retained, separately, for as long as the participant is on the database. If participants elect to take part in another study carried out by the Jenner Institute, personal information and medical information including blood test results may be accessed to avoid unnecessary repetition.

## 15 FINANCING AND INSURANCE

### 15.1 Financing

The study is funded through a grant from MultiViVax, a European Commission Horizon 2020 funded project (733073), which funds work to develop candidate multi-stage malaria vaccines through innovative trial designs in malaria-endemic areas.

### 15.2 Insurance

The University has a specialist insurance policy in place which would operate in the event of any participant suffering harm as a result of their involvement in the research (Newline Underwriting Management Ltd, at Lloyd's of London).

### 15.3 Compensation

Volunteers will be compensated for their time and for the inconvenience caused by procedures as below.

- Screening visit £25
- Subsequent visits:
  - Travel expenses £15 per visit
  - Inconvenience of blood tests: £10 per blood donation
  - Time required for visit: £20 per hour

Where travel expenses are greater than £15 per visit because the volunteer lives outside the city of the trial site, the volunteer may be given further reimbursement to meet the cost of travel necessary for study visits at the Investigator's discretion.

	Time in trial (approx.)	Maximum visits	Maximum volume of blood taken (mls)	Compensation
Groups 1-3	1 year	16	972	£790

**Table 8:** Estimated compensation amounts.

## 16 APPENDICES

### Appendix A: laboratory values for exclusion

Laboratory parameters for inclusion/exclusion in the trial will be considered on an individual basis, with Investigator discretion for interpretation of results and the need for repeated or further tests. In general, volunteers will be excluded if a result at screening constitutes what would qualify as a grade 1 (or higher) laboratory adverse event, according to the laboratory adverse event tables (filed in the TMF), on repeat of an abnormal test result. Urinalysis at screening will be assessed as per the table below:

URINE ANALYSIS (using MULTISTIX)	
Protein*	2+ or Protein creatinine ratio of $\geq 50$ mg/mmol
Blood <sup>£</sup>	2+ on two dipstick tests
Glucose	1+

**Table 9:** Urinalysis assessment.

\*In the event of the dipstick testing positive for protein with  $\geq 1+$  protein urine should be sent for a protein creatinine ratio.

<sup>£</sup> In the event of urine dipstick testing positive for  $\geq 1+$  blood with, or without, protein, a repeat dipstick test will be carried out to confirm haematuria. In volunteers of child-bearing potential, a menstrual history will be taken to elicit whether the participant is currently menstruating and if they are, urine dipstick will be repeated after 1 - 2 weeks. If blood and/or proteinuria persist in any volunteer, an interpretation of the results will be undertaken by the Investigator on an individual basis to determine if they will be excluded from the trial, and the appropriate follow-up arranged.

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