Comparison of a progestin-primed ovarian stimulation protocol with a flexible GnRH antagonist protocol in patients with polycystic ovary syndrome who are participating in an IVF programme: study protocol for a randomised controlled trial

Ningling Wang, Qianqian Zhu, Meng Ma, Zhou Liang, Yu Tao, Yun Wang ♦, Yanping Kuang

ABSTRACT

Introduction Women with polycystic ovary syndrome (PCOS) undergoing in vitro fertilization (IVF) protocols are typically characterised by an increased number of oocytes retrieved. The oocytes are often of poor quality, leading to lower pregnancy rates, higher miscarriage rates and an increased risk of developing ovarian hyperstimulation syndrome (OHSS). Since our previous preliminary study showed that a novel progestin-primed ovarian stimulation protocol (PPOS) protocol blocked the luteinising hormone (LH) surge during IVF and achieved a higher pregnancy rate with a lower incidence of OHSS, we designed a prospective randomised controlled trial to compare the efficacy and safety of this PPOS protocol with the flexible gonadotropin-releasing hormone (GnRH) antagonist protocol in patients with PCOS who are undergoing IVF procedures.

Methods and analysis Patients with PCOS will be randomised to one of two controlled ovarian stimulation regimens—GnRH antagonist or PPOS—using a computer-generated random number. A freeze-all strategy using embryo vitrification techniques and frozen embryo transfer will be performed in both groups. The primary outcome is the live-birth rate per transfer. Secondary outcomes include the incidence of premature LH surges, the duration and total dose of human menopausal gonadotropin stimulation, the number of oocytes retrieved, the incidence of moderate or severe OHSS, the number of embryos available for transfer, implantation rates, clinical pregnancy rates, pregnancy loss rates, ectopic pregnancy rates, pregnancy and neonatal complications, and congenital anomalies. The necessary sample size for this trial was estimated as 392 participants, with 196 participants in each group. Intention-to-treat analysis was used in processing our experimental data.

Ethics and dissemination This study was approved by the Institutional Review Board of the hospital (2016-133-T82). The trial will be conducted according to the principles of the World Medical Association’s Declaration of Helsinki and in accordance with Good Clinical Practice standards. The findings of this trial will be published in a peer-reviewed journal.

Trial registration number ChiCTRIPR16009580.

INTRODUCTION

Polycystic ovary syndrome (PCOS)—a common metabolic dysfunction and heterogeneous endocrine disorder—is the most common cause of anovulatory infertility, affecting approximately 10%–18% of reproductive age women worldwide.1 2 It is usually characterised by a clustering of hyperandrogenism, hypersecretion of luteinising hormone (LH) and hyperinsulinaemia, which could result in the arrest of ovarian
Women with PCOS undergoing IVF treatment because of infertility are increasing in number, and these patients have been well described, typically characterised by producing an increased number of oocytes; however, the oocytes retrieved from PCOS women are often of poor quality—leading to lower fertilisation, implantation, and pregnancy rates and a higher miscarriage rate and incidence of ovarian hyperstimulation syndrome (OHSS). Increasing evidence raises the issue that impaired oocyte maturation and developmental competence in women with PCOS are possibly linked to abnormal endocrine/paracrine factors, metabolic dysfunction and alterations in the intrafollicular microenvironment during folliculogenesis and follicle maturation. Thus, it will be of crucial importance to optimise clinical stimulation protocols to improve oocyte maturation and embryonic developmental competence in order to enhance pregnancy outcomes in women with PCOS undergoing IVF treatment.

Several clinical ovarian stimulation protocols have been used thus far in women with PCOS undergoing IVF treatment to prevent a premature LH surge during controlled ovarian stimulation (COS); these primarily include gonadotropin-releasing hormone (GnRH) agonist or antagonist protocols. GnRH antagonists can competitively inhibit endogenous GnRH and produce an immediate and rapid decline in LH and follicle-stimulating hormone (FSH) levels without the flare effect of a GnRH agonist, and their administration by subcutaneous injection in the late follicular phase prevents an LH surge. Previous randomised controlled trials of women with PCOS in which a GnRH antagonist protocol was compared with a conventional GnRH agonist protocol have reported similar clinical pregnancy rates for the two groups; however, IVF cycles with GnRH antagonists had lower gonadotropin requirements, a shorter duration of stimulation and a lower incidence of OHSS.

With progress in embryo vitrification techniques, many studies have suggested that pregnancies that arise from the transfer of frozen-thawed IVF embryos appear to have better perinatal and pregnancy outcomes. Similarly, a recent study conducted in China also reported that frozen embryo transfer (FET) resulted in a higher frequency of live births and a lower frequency of pregnancy loss and OHSS compared with fresh embryo transfer among infertile patients with PCOS. Thus, GnRH antagonist regimens combined with a freeze-all strategy for women with PCOS are currently accepted as the most routine IVF procedures.

We first used progestins to prevent a premature LH surge during COS in a patient population with PCOS—that is, progestin-primed ovarian stimulation (PPOS)—and the prospective pilot trial showed that the progestin administered orally persistently suppressed LH concentrations in the serum without an LH surge during ovarian stimulation. Subsequently, with the freeze-all strategy, the FET cycles thus achieved higher ongoing pregnancy (58.67%) and live-birth rates (54.67%) relative to the previously reported live-birth rate of approximately 40% with GnRH antagonists in PCOS women undergoing IVF treatment. These data indicated that progestin treatment might improve oocyte quality compared with a GnRH antagonist during COS in these patients, plus there were the advantages of an oral administration route instead of repeated injections of GnRH antagonist, a lower drug price and more control over LH levels, which can reduce the patients’ discomfort and costs. However, there are currently no data comparing the efficacy and safety of the PPOS and GnRH antagonist protocols in improving the oocyte quality for PCOS patients. Therefore, we hypothesised that progestin would show some superiority in effectively improving oocyte maturation and developmental competence compared with using a GnRH antagonist. Thus, we have developed the present well-designed, large-sample prospective trial to investigate the potential of using progestin in women with PCOS who are undergoing IVF treatment.

METHODS AND ANALYSIS

Objectives

The purpose of this trial is to compare the efficacy and safety of the PPOS protocol to the flexible GnRH agonist protocol in patients with PCOS who are undergoing IVF procedures.

Design of the trial

In this prospective, non-inferiority trial, we will compare the efficacy and safety of the GnRH antagonist and PPOS protocols in 392 patients with PCOS undergoing IVF. Participants with PCOS need to undergo IVF treatment because of infertility and will continue to be enrolled in the Shanghai Ninth People’s Hospital affiliated with Shanghai Jiaotong University School of Medicine. This study has been approved by the Institutional Review Board (IRB) of Shanghai Ninth People’s Hospital (2016-133-T82). Before the trial, investigators are required to provide all information related to the clinical trial, including the possible benefits and risks, other therapeutic choices and the right to withdraw, via a written consent form approved by the IRB. After being provided with sufficient time to decide whether to participate and the opportunity to ask questions, all participants will be required to provide written informed consent before study inclusion.

This protocol has been written in accordance with the Standard Protocol Items of the Recommendations for Interventional Trials (SPIRIT). A SPIRIT checklist is provided in online supplemental file 1. Any significant modification to the protocol requires a formal protocol amendment with unanimous agreement by the project team and approval by our IRB. Minor administrative
changes to the protocol will be documented in a memorandum. The study flowchart is shown in figure 1.

Eligibility criteria
Eligible patients need to meet all of the following inclusion criteria and there are no listed exclusion criteria.

Inclusion criteria
The following are our inclusion criteria:
1. Women who have a history of infertility ≥1 year.
2. Women aged between 20 and 35 years.
3. Women diagnosed with PCOS according to the modified Rotterdam criteria: oligomenorrhea or amenorrhea, together with the presence of ≥12 antral follicles (≤9 mm) and/or ovarian volume >10 mL on transvaginal ultrasonographic scanning, and/or clinical/biochemical hyperandrogenism.21 Other causes of hyperandrogenism and ovulation dysfunction—including tumours, congenital adrenal hyperplasia, hyperprolactinaemia and thyroid dysfunction—were excluded.

Exclusion criteria
Women who met any of the following criteria were excluded:
1. Endometriosis grade 3 or higher.
2. Documented ovarian failure, including basal FSH above 10 IU/L.
3. Clinically significant systemic disease, or other endocrine disorders, including 21-hydroxylase deficiency, uncorrected thyroid disease or suspected Cushing’s syndrome.
4. Patients who in the previous 3 months received hormonal treatments or other medications known to affect reproductive function, including oral contraceptives and GnRH agonists.
5. Patients who had a history of unilateral oophorectomy, recurrent spontaneous abortion (defined as three or more previous spontaneous pregnancy losses), congenital or acquired uterine malformations, abnormal results on parental karyotyping or medical conditions that contraindicated assisted reproductive technology or pregnancy.
6. Inability to comply with the study procedures.

Recruitment of study participants
The trial protocol (12 January 2017, version 2.0) was approved by the IRB of Shanghai Ninth People’s Hospital. Recruitment into the trial started in March 2017 and will continue until 392 participants are registered.
participants who meet the abovementioned criteria will receive oral and written participant information from their attending physician before giving written informed consent. This study is being conducted at the Department of Assisted Reproduction of Shanghai Ninth People’s Hospital (Shanghai, China).

**Randomisation**
Volunteers who met the abovementioned criteria will be allocated randomly to one of the two study groups in a ratio of 1:1 on menstrual cycle day 3. The allocation sequence will be generated with computer-generated random numbers. Both study investigators and participants will be aware of the allocation after ovarian stimulation. The doctors, embryologists and research coordinators involved in oocyte retrieval and embryo transfer will be blinded to the intervention group assignments in the trial.

**Treatment method**

**Ovarian stimulation protocols**

**PPOS protocol**
The PPOS protocol is as previously reported: human menopausal gonadotropin (hMG) (Anhui Fengyuan Pharmaceutical, China) at a dose of 150 to 225 IU/day and 10 mg of medroxyprogesterone acetate (MPA) (Beijing Zhong Xin Pharmaceutical, China) are administered daily from day 3 of menstruation until the trigger day. The starting dose of hMG is 150 IU/day for patients with a high antral follicle count >20 or slightly elevated basal FSH (7–10 IU/L), and a daily dose of 225 IU hMG is used for the other patients. The dose was adjusted after day 5 of stimulation based on the ovarian response as assessed by serum hormone levels and transvaginal ultrasonography. As soon as three dominant follicles reached 18 mm in diameter, the final stage of oocyte maturation was co-triggered by triptorelin (100 µg) (Ferring International Center SA, Germany) and 1000 IU of human chorionic gonadotropin (hCG) (Lizhu Pharmaceutical Trading, China).

**GnRH antagonist protocol**
In the flexible GnRH antagonist protocol (antagonist group), we initiated daily s.c. administration of ganirelix (0.25 mg, Orgalutran, Organon, The Netherlands) when at least one of the following criteria was fulfilled: (1) the presence of at least one follicle measuring 12 mm; (2) serum E2 levels of 600 pg/mL or (3) serum LH levels of 10 IU/L. hMG (150–225 IU) is administered daily from menstrual cycle day 3, and follicular monitoring is performed every 2 to 3 days after 5 days of injections. The dose of hMG is adjusted according to the ovarian response, as monitored by ultrasonography and the measurement of serum sex steroids. Treatment with hMG and GnRH antagonist continue daily until the day when final oocyte maturation is triggered. When the dominant follicles reach a diameter of 18 mm, the final stage of oocyte maturation is induced with injections of 100 µg of triptorelin s.c combined with 1000 IU of hCG i.m. Transvaginal ultrasound-guided oocyte retrieval was performed 36 hours later.

**Embryo culture, evaluation and cryopreservation**
All of the follicles greater than 10 mm in diameter are aspirated. The oocytes are inseminated approximately 4–6 hours after follicular aspiration by a conventional IVF method or intracytoplasmic sperm injection, based on the sperm quality. Morphological criteria are then used for embryo scoring. On day 3, high-quality embryos are cryopreserved by means of vitrification in both groups undergoing FET. While the non-top-quality embryos are cultured for an extended period, only blastocysts with good morphology are frozen on days 5 or 6 according to Cummins’ criteria.

**Endometrial preparation and frozen-thawed embryo transfer**
It was previously reported that letrozole use is relevant and, if necessary, can be combined with a low dose of hMG to mildly stimulate follicular growth for endometrial preparation in frozen-thawed embryo transfer cycles. We therefore administered 5 mg of letrozole from cycle days 3 to 7 and then monitored follicle growth beginning on day 10. At times, the treatment includes a low dose of hMG (75 IU/day) to stimulate the growth of follicles and the endometrial lining. Finally, we administered 5000 IU of hCG to trigger ovulation, and the timing of FET was performed as described elsewhere. For patients with a thin endometrium or failed embryo transfer after mild stimulation cycles, we adopt hormonal replacement therapy as described elsewhere. The maximal number of transferred embryos is two per transfer cycle. When pregnancy is achieved, progesterone supplementation is continued until 10 weeks of gestation.

**Outcome measurements**

**Primary endpoints**
The primary outcome is the live-birth rate per randomised cycle. A live birth is defined as the delivery of any viable infant at 28 weeks or longer gestation after embryo transfer.

**Secondary endpoints**
Secondary outcome measures are the incidence of premature LH surges, duration of hMG stimulation, total dose of hMG, E2, and progesterone concentrations on the trigger day, cycle cancellation rate, number of cumulus-oocyte complexes (COCs) retrieved, number of metaphase II oocytes, fertilisation rates, number of viable embryos for transfer, biochemical pregnancy and clinical pregnancy rates, implantation rates, ongoing pregnancy and live-birth rates per transfer, and cumulative live-birth rates (including all frozen embryo transfers from a single IVF cycle).

A premature LH surge is defined as an increase in serum LH levels more than twice the baseline level or a serum LH >15 mIU/mL and increased serum progesterone level >2.5 ng/mL on the trigger day. Biochemical
pregnancy was defined as a hCG concentration of more than 10 mIU/mL, as measured 14 days after embryo transfer. An ongoing pregnancy and clinical pregnancy were defined as the presence of a gestational sac with fetal heartbeat detection at 12 weeks and at 6–7 weeks of gestation, respectively. All of the pregnancy and neonatal outcomes were obtained through a review of medical records.

**Safety endpoints**

The safety endpoints include the incidence of moderate or severe OHSS, miscarriage rates, ectopic pregnancy, pregnancy complications, congenital anomalies and neonatal complications.

The definition and classification of OHSS are adopted according to the accepted criteria previously reported.25 26 Mild OHSS is diagnosed by the presence of abdominal distension and/or discomfort with or without nausea, vomiting, abdominal pain, dyspnoea, diarrhoea, enlarged ovaries and no important alterations in laboratory features. Moderate OHSS is diagnosed by ultrasonographic evidence of ascites (in addition to the above mild clinical features), with haemoconcentration (Hct >41%) and elevated white cell count (>15×10⁹/L). Severe OHSS is diagnosed by the presence of clinical evidence of ascites and/or hydrothorax, severe dyspnoea, oliguria/anuria, intractable nausea/vomiting, severe haemoconcentration (Hct >55%), white cell count 25×10⁹/L, creatinine clearance (CrCl) <50 mL/min, creatinine (Cr) >1.6 mg/dL, sodium (Na+) <135 mEq/L, potassium (K+) >5 mEq/L, elevated liver enzymes and so on.27

**Data management, monitoring, safety and auditing**

The time points for enrolment, intervention and data collection are described in figure 2. Study-related information—such as participant identity and data and medical records related to the study—will remain confidential.

Data collected will be entered and stored in password-protected electric case report forms (eCRFs) with access only allowed to the researchers involved. As with previous reports, we will use an automated system for validating the data against a set of predefined rules that query investigator data entered as invalid, illogical or incomplete. Data elements critical to the trial are double-checked to confirm the accuracy of the data entered compared with the source documents.28

The data monitoring committee comprises three clinical trial specialists, including a biostatistican, who were not associated with this study. The committee will meet at least two times a year, and all of the data obtained from the current trial will be checked by the committee. Monitors will ensure that the investigational team is complying with the study protocol and Good Clinical Practice (GCP) standards that the data and adverse events (AEs) are accurately and appropriately recorded in the eCRFs, that severe AEs (SAEs) are reported to the trial coordinator and the investigational drug provider and that those meeting the SAE reporting criteria are reported to the IRB. All participants with AEs will be followed up during the course of the AE until their resolution or for 4 weeks after the end of the trial. All SAEs will be reported to all investigators, discussed through a web-based AE reporting system and will be reported to the Pharmaceuticals and Medical Devices Agency, if necessary.

**Sample size and power calculations**

Previous studies have reported that the anticipated live-birth rate in the GnRH antagonist protocol followed by FET was over 40.0%, and our recent double-blind randomised crossover clinical trial of women with PCOS showed that with the PPOS protocol, the ongoing pregnancy rate per transfer was 58.67% (44/75) and the live-birth rate was 54.67% (41/75). Therefore, we hypothesised that the novel PPOS protocol would achieve a comparable live-birth rate for PCOS patients undergoing IVF treatment.

Therefore, with respect to power calculations, we designed this study to have a power of 80% at a two-sided significance level of 0.05 to detect an absolute difference of 10 percentage points in the live-birth rate between the two study groups (based on anticipated rates of 54.67% in the PPOS group versus 40% in the GnRH antagonist group, both after FET) by means of Pearson’s χ² test. We calculated that at least 178 patients per study group were required, a number that we increased to 196 to allow for a dropout rate of 10%.

**Statistical analysis**

We will perform intention-to-treat analyses to compare the live-birth rates and the incidence of moderate and severe OHSS in the two study groups. Categorical data are represented as percentages and frequencies; differences in these measures between the two study groups will be assessed by means of Chi-square analysis, with the use of Fisher’s exact-probability test used for expected frequencies of less than 5. Continuous data are expressed as the means (±SD), with Student’s t-tests or a Kruskal-Wallis test for between-group differences. A multivariate logistic regression will be used to adjust for the effects of baseline characteristics. All of the analyses were performed with SPSS software V.17.0.

**Patient and public involvement**

Patients and the public are not involved in the process of the study. The participants will be informed of the study results via peer-reviewed journals, conference presentations and the Clinical Research Information Service.

**Ethics and dissemination**

This study was approved by the IRB of Shanghai Ninth People’s Hospital (2016-133-T82). The trial will be conducted according to the principles of the World Medical Association’s Declaration of Helsinki and in accordance with GCP standards. The trial findings will be published in peer-reviewed journals. All confidential
patient data will be protected. The patients' identities will not be disclosed.

DISCUSSION

A high-quality oocyte is imperative for fertility, but PCOS patients consistently suffer from poor oocyte quality, resulting in decreased fertilisation rates, impaired pregnancy rates and higher miscarriage rates. An increasing number of studies have shown that the production of oocytes with lower developmental competence from PCOS patients is related to abnormal endocrine/paracrine factors, metabolic dysfunction and alterations in the intrafollicular microenvironment during folliculogenesis and follicle maturation, including hypersecretion of LH, hyperandrogenism and hyperinsulinaemia. Improving impaired oocyte developmental competence in women with PCOS to enhance pregnancy outcomes is therefore an urgent issue that requires resolution.

Women with PCOS typically demonstrate tonic hypersecretion of LH during the follicular phase, and high LH levels during folliculogenesis may directly activate premature meiotic processes and damage the oocyte nucleus, leading to apoptosis. Hypersecretion of LH may also promote premature granulosa cell luteinisation and follicular atresia in small antral follicles, causing premature oocyte maturation via inhibition of oocyte maturation

<table>
<thead>
<tr>
<th>Time-point</th>
<th>Enrolment</th>
<th>Allocation</th>
<th>Study period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Screening</td>
<td>Menstrual cycle</td>
<td>Ovarian stimulation cycle monitor</td>
</tr>
<tr>
<td>Identification</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eligibility screen</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline measures</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Informed consent</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Randomisation allocation</td>
<td>×</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 Timetable of the study period.
inhibitors, all of which compromise the quality of both oocytes and embryos. Elevated serum LH levels also contribute to hyperandrogenaemia by directly stimulating follicular theca cells to increase androgen biosynthesis. It has been suggested that increased androgen concentrations in the follicular fluid may then exert a negative impact on oocyte developmental competence by decreasing oocyte calcium oscillations, consequently inhibiting oocyte cytoplasmic maturation and thus affecting meiotic maturation.

Other studies have suggested that elevated testosterone—either directly or indirectly—decreases the rates of in vitro maturation (IVM), fertilisation and embryonic development. All of the aforementioned studies suggested that elevated follicular LH and androgen levels exert a detrimental effect on oocyte/embryo quality and pregnancy outcomes in PCOS patients, although some studies showed that premature luteinisation did not affect the pregnancy rates.

In our preliminary studies of PCOS women undergoing IVF treatment, progesterin (MPA) administered orally persistently suppressed LH levels during ovarian stimulation, and we observed no cases of a premature LH surge. When this was followed by freeze-all and FET, a better ongoing pregnancy rate (58.67%) and live-birth rate (54.67%) were achieved. The better pregnancy outcomes for PCOS patients using our novel PPOS protocol in IVF might be explained by the following: First, progesterin administered orally from the early follicular phase can inhibit the synthesis and secretion of LH by reducing the frequency of the GnRH pulse, which may completely or partially correct abnormally high LH levels and hyperandrogenism in the intrafollicular milieu during folliculogenesis and follicle maturation in women with PCOS. Second, some previous studies have shown that progesterone plays a crucial role in oocyte maturation, fertilisation and embryonic development, both directly and indirectly. PCOS women manifest an accelerated conversion of progesterone to androstenedione in theca cells because of high LH stimulation, which leads to a paucity of progesterone in the intrafollicular microenvironment. Therefore, there is a theoretical benefit from the addition of progesterin during COS for patients with PCOS that would allow for normal follicle development in an appropriate microenvironment and improve oocyte quality, thus enhancing pregnancy outcomes.

Live-birth rates are the recommended end point for infertility trials. The GnRH antagonist regimen followed by vitrified embryo transfer cycles combined with a freeze-all strategy for women with PCOS has recently become accepted as the most common routine IVF procedure. Acceptance is based on either the previous prospective or retrospective clinical study results. We therefore selected the GnRH antagonist protocol as the control group to evaluate the efficacy and safety of our novel PPOS protocol in women with PCOS who are undergoing IVF treatment.

To our knowledge, this is the first randomised controlled trial to examine the efficacy and safety of PPOS ovarian stimulation protocols in IVF for women with PCOS compared with typical GnRH antagonist protocols. The present study results will add to the current knowledge base regarding COS and have the potential to establish a promising treatment option for PCOS patients.

**Trial status**

The present study was conceived and designed in 2016. The registry number is ChiCTRIPR16009580, and it was registered on 12 October 2016 (http://www.chictr.org.cn/showproj.aspx?proj=16352). The first participant was randomised on 20 March 2017. We will complete recruitment in March 2021, and our follow-up of pregnancies from FET will be ongoing. This protocol, version 2, was approved on 12 January 2017.

**Author affiliations**

Department of Assisted Reproduction, Shanghai Ninth People’s Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

**Acknowledgements** We gratefully acknowledge all staff and patient advisers in the Department of Assisted Reproduction in Shanghai Ninth People’s Hospital for their support and cooperation. We thank LetPub (www.letpub.com) for its linguistic assistance during the preparation of this manuscript.

**Contributors** NW participated in the design of the study. YW participated in the design and development, including the statistical analysis plan. QZ, MM, ZL and YT were responsible for collection of data. YK conceived of the study and guided the design. All authors read and approved the final manuscript.

**Funding** This study was funded by the National Nature Science Foundation of China (No. 475 8101527, 31770989).

**Competing interests** None declared.

**Patient consent for publication** Patients and the public are not involved in the process of the study. The participants will be informed of the study results via peer-reviewed journals, conference presentation and the Clinical Research Information Service.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

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

**ORCID iD**

Yun Wang http://orcid.org/0000-0002-5640-5010

**REFERENCES**


## Additional file 1: SPIRIT checklist

<table>
<thead>
<tr>
<th>Section/item</th>
<th>Item No</th>
<th>Description</th>
<th>Addressed on page number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Administrative information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>1</td>
<td>Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym</td>
<td>P1</td>
</tr>
<tr>
<td>Trial registration</td>
<td>2a</td>
<td>Trial identifier and registry name. If not yet registered, name of intended registry</td>
<td>P3, P19</td>
</tr>
<tr>
<td></td>
<td>2b</td>
<td>All items from the World Health Organization Trial Registration Data Set</td>
<td>-</td>
</tr>
<tr>
<td>Protocol version</td>
<td>3</td>
<td>Date and version identifier</td>
<td>P19</td>
</tr>
<tr>
<td>Funding</td>
<td>4</td>
<td>Sources and types of financial, material, and other support</td>
<td>P20</td>
</tr>
<tr>
<td>Roles and responsibilities</td>
<td>5a</td>
<td>Names, affiliations, and roles of protocol contributors</td>
<td>P1, P20</td>
</tr>
<tr>
<td></td>
<td>5b</td>
<td>Name and contact information for the trial sponsor</td>
<td>P1</td>
</tr>
<tr>
<td></td>
<td>5c</td>
<td>Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities</td>
<td>P20</td>
</tr>
<tr>
<td></td>
<td>5d</td>
<td>Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee)</td>
<td>P14, P7</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background and rationale</td>
<td>6a</td>
<td>Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention</td>
<td>P5-7</td>
</tr>
<tr>
<td></td>
<td>6b</td>
<td>Explanation for choice of comparators</td>
<td>P5-7</td>
</tr>
<tr>
<td>Objectives</td>
<td>7</td>
<td>Specific objectives or hypotheses</td>
<td>P7</td>
</tr>
<tr>
<td>Section</td>
<td>Page Numbers</td>
<td>Details</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Trial design</td>
<td>P7-8</td>
<td>Description of trial design including type of trial (e.g., parallel group, crossover, factorial, single group), allocation ratio, and framework (e.g., superiority, equivalence, noninferiority, exploratory)</td>
<td></td>
</tr>
<tr>
<td>Methods: Participants, interventions, and outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study setting</td>
<td>P7-8</td>
<td>Description of study settings (e.g., community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained</td>
<td></td>
</tr>
<tr>
<td>Eligibility criteria</td>
<td>P8-9</td>
<td>Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (e.g., surgeons, psychotherapists)</td>
<td></td>
</tr>
<tr>
<td>Interventions</td>
<td>P10-12, Figure 1</td>
<td>Interventions for each group with sufficient detail to allow replication, including how and when they will be administered</td>
<td></td>
</tr>
<tr>
<td>Interventions</td>
<td>P10-12</td>
<td>Criteria for discontinuing or modifying allocated interventions for a given trial participant (e.g., drug dose change in response to harms, participant request, or improving/worsening disease)</td>
<td></td>
</tr>
<tr>
<td>Interventions</td>
<td>P10-12</td>
<td>Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (e.g., drug tablet return, laboratory tests)</td>
<td></td>
</tr>
<tr>
<td>Interventions</td>
<td>P10-12</td>
<td>Relevant concomitant care and interventions that are permitted or prohibited during the trial</td>
<td></td>
</tr>
<tr>
<td>Outcomes</td>
<td>P12-13</td>
<td>Primary, secondary, and other outcomes, including the specific measurement variable (e.g., systolic blood pressure), analysis metric (e.g., change from baseline, final value, time to event), method of aggregation (e.g., median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended</td>
<td></td>
</tr>
<tr>
<td>Participant timeline</td>
<td>See Figure 2</td>
<td>Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for participants. A schematic diagram is highly recommended (see Figure)</td>
<td></td>
</tr>
<tr>
<td>Sample size</td>
<td>P15-16</td>
<td>Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations</td>
<td></td>
</tr>
<tr>
<td>Recruitment</td>
<td>P9</td>
<td>Strategies for achieving adequate participant enrolment to reach target sample size</td>
<td></td>
</tr>
<tr>
<td>Methods: Assignment of interventions (for controlled trials)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Allocation:

Sequence generation  16a  Method of generating the allocation sequence (eg, computer-generated random numbers), and list of any factors for stratification. To reduce predictability of a random sequence, details of any planned restriction (eg, blocking) should be provided in a separate document that is unavailable to those who enrol participants or assign interventions  P10

Allocation concealment mechanism  16b  Mechanism of implementing the allocation sequence (eg, central telephone; sequentially numbered, opaque, sealed envelopes), describing any steps to conceal the sequence until interventions are assigned  P10, P7,P9

Implementation  16c  Who will generate the allocation sequence, who will enrol participants, and who will assign participants to interventions  P10, P7,P9

Blinding (masking)  17a  Who will be blinded after assignment to interventions (eg, trial participants, care providers, outcome assessors, data analysts), and how  P10,P14

  17b  If blinded, circumstances under which unblinding is permissible, and procedure for revealing a participant’s allocated intervention during the trial  P16

Methods: Data collection, management, and analysis

Data collection methods  18a  Plans for assessment and collection of outcome, baseline, and other trial data, including any related processes to promote data quality (eg, duplicate measurements, training of assessors) and a description of study instruments (eg, questionnaires, laboratory tests) along with their reliability and validity, if known. Reference to where data collection forms can be found, if not in the protocol  P14-15

  18b  Plans to promote participant retention and complete follow-up, including list of any outcome data to be collected for participants who discontinue or deviate from intervention protocols  P14-15

Data management  19  Plans for data entry, coding, security, and storage, including any related processes to promote data quality (eg, double data entry; range checks for data values). Reference to where details of data management procedures can be found, if not in the protocol  P14-15

Statistical methods  20a  Statistical methods for analysing primary and secondary outcomes. Reference to where other details of the statistical analysis plan can be found, if not in the protocol  P15-16
20b Methods for any additional analyses (eg, subgroup and adjusted analyses) P14-15

20c Definition of analysis population relating to protocol non-adherence (eg, as randomised analysis), and any statistical methods to handle missing data (eg, multiple imputation) P14-15

Methods: Monitoring

Data monitoring 21a Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed P14-15

21b Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial P14-15

Harms 22 Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct P14-15

Auditing 23 Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor P14-15

Ethics and dissemination

Research ethics approval 24 Plans for seeking research ethics committee/institutional review board (REC/IRB) approval P16

Protocol amendments 25 Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC/IRBs, trial participants, trial registries, journals, regulators) P16,P19

Consent or assent 26a Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32) P16,P20

26b Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable -
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidentiality</td>
<td>27</td>
<td>How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial</td>
</tr>
<tr>
<td>Declaration of interests</td>
<td>28</td>
<td>Financial and other competing interests for principal investigators for the overall trial and each study site and disclosure of contractual agreements that limit such access for investigators</td>
</tr>
<tr>
<td>Access to data</td>
<td>29</td>
<td>Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators</td>
</tr>
<tr>
<td>Ancillary and post-trial care</td>
<td>30</td>
<td>Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation</td>
</tr>
<tr>
<td>Dissemination policy</td>
<td>31a</td>
<td>Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions</td>
</tr>
<tr>
<td></td>
<td>31b</td>
<td>Authorship eligibility guidelines and any intended use of professional writers</td>
</tr>
<tr>
<td></td>
<td>31c</td>
<td>Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code</td>
</tr>
<tr>
<td>Appendices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Informed consent materials</td>
<td>32</td>
<td>Model consent form and other related documentation given to participants and authorised surrogates</td>
</tr>
<tr>
<td>Biological specimens</td>
<td>33</td>
<td>Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable</td>
</tr>
</tbody>
</table>