Recommendations guide for experimental animal models in stroke research


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Abstract

Introduction: The progress of effective therapies for stroke has become a challenging task for both researchers and clinicians. Some pitfalls in clinical trials might have their origins in the pre-clinical experimental ischaemic models for the evaluation of potential neuro-protective agents.

Methods: We aim to standardise the methods for the development of stroke animal models throughout Spain, to produce document with appropriate recommendations and best practice in order to improve experimental methods in the field of stroke research.

Results: Members of several experienced stroke research groups prepared a guide with recommendations in the application of focal cerebral ischaemic models. The main features of this guide are based on the selection of the most appropriate animal model, taking in account the objective of the study, the species, strain, age, sex of animals, as well as risk factors. The experimental design must include a sham control group and the sample size calculation. Animal randomisation and blind analysis, masked assessment of outcomes, monitoring of body temperature and cerebral blood flow, and the reporting of
Introduction

As strokes are one of the most common causes of permanent disability and the first cause of death among Spanish women, the search for effective therapies to treat ictus currently constitutes an enormous challenge for both basic and clinical researchers. Despite the evaluation of over 50 neuroprotective agents in Phase III clinical trials that have revealed therapeutic effects in cerebral ischaemia models with rats, mice or gerbils, none has been shown to have conclusive effects on humans. Currently the only approved therapy is treatment with tissue plasminogen activator in the hyperacute phase of the ischaemic ictus. However, despite their great efficacy, the fact that it must be administered within a narrow therapeutic window of no more than 4 and a half hours from the start of symptoms and the risk of an increase in cerebral bleeding have given rise to fewer than 5% of stroke patients benefiting from thrombolytic therapy. All of this means that it is fundamental to identify new neuroprotective or neuroreparative agents that may be useful for treating ictus and to understand why we have witnessed so many therapeutic failures when promising drugs are transferred from the laboratory to clinical practice.

Some of the reasons the neuroprotective drugs have not been shown to be effective in clinical trials are probably due to a failure in the development and mode of evaluation in preclinical models of the agents neuroprotective in the models animals of ischaemia cerebral. The critical factors to be optimized because they affect the success rate and the variability of the models include, among others, the selection of each experimental model depending on the purpose of the study, the use of appropriate anaesthesia, the maintenance and monitoring of animals in a physiological setting and the observation and analysis of the results eliminating any kind of bias. The present paper reviews the most critical aspects for the development of animal experimentation models for the study of ictus and publishes the most important recommendations in their application.
Purpose

The purpose of the “Recommendations guide for experimental animal models in stroke research” is to unify the methodology used in the development of experimental models, clarify and establish the critical factors to optimize the results and improve research in the field of cerebral ischaemia nationwide. It sets out the common action lines of the members of the different Spanish animal experimentation laboratories that took part. The guide was produced following the meeting entitled Lost in (stroke) translation. Barcelona Think Tank Project (July 17th-18th, 2009) with the support of the RENEVAS network and constitutes a document for the future consensus on actions and recommendations based on the aspects dealt with at the meeting and the discussions of the committee members. The following section describes the main points it contains.

Development

Selection of the cerebral ischaemia animal model most suitable for each study

The correct cerebral ischaemia animal model to be used will depend on the purpose of the study. The choice of model will mainly be based on the ischaemic physiopathology process the study is focusing on and will take into account the reproducibility of the variables to be studied for each model. The selection of the model will depend, among other factors, on the permanent or transient mode of ischaemia applied, depending on whether or not there is an interest in the pathophysiology of the ischaemic reperfusion; on the intensity of the cerebral ischaemia and the involvement of the brain areas desired for the study; on the duration of the experimental study (acute or chronic study) and on application in drug administration. Table 1 describes the most important recommendations on the type of model to be used depending on the purpose of the study.

Selection of species/strain, age, sex and risk factors

To select the best model, it will be essential to consider the type of animal to be used, with the following factors having great relevance: i) species, ii) strain, iii) sex, iv) age and v) risk factors. The main characteristic to bear in mind is that the neurovascular anatomy differs greatly from one strain to another. The result in terms of the size of the ischaemic lesion will vary greatly depending on the existence of a larger or smaller number of collateral ramifications irrigating the territory of the MCA. The rodent species used by our groups are rats and mice. The most appropriate rat strains for these models are the Wistar strain, although the use of rats from the Wistar Kyoto sub-strain is not advised as they

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**Table 1 Recommendations of the cerebral focal ischaemia model to be used by study type**

<table>
<thead>
<tr>
<th>Model</th>
<th>Study</th>
<th>Recommendations for application</th>
<th>Recommendations for “non-use”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraluminal suture model; proximal occlusion of the MCA</td>
<td>Neuroprotection in acute phase (studies over 24-72 h)</td>
<td>Transient: use occlusion for 1 to 2 hours  &lt;br&gt;Permanent: it is advisable to perform an angiography using magnetic resonance to confirm the occlusion of the artery throughout the study period. It is advisable to have an extra group to confirm the protective action of the agent in the long term (23 weeks)  &lt;br&gt;Monitoring for at least 21 days</td>
<td>Do not use when using thrombolytic therapy with tPA</td>
</tr>
<tr>
<td>Embolic Model</td>
<td>Neurorepair (studies over several weeks)</td>
<td>If the study also includes the assessment of the incidence of haemorrhagic transformation, it is advisable to use hypertensive rats</td>
<td></td>
</tr>
<tr>
<td>Endothelin model</td>
<td>Application of thrombolytic drugs and co-treatments with these medicines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCA distal occlusion model</td>
<td>Animal simulation of a lacunar infarction</td>
<td>Do not use any light source other than cold light to induce thrombosis  &lt;br&gt;If mice are used, do not apply unilateral or bilateral occlusion of the carotid arteries. Do not use if the oedema is the target for the study, as craniotomy is necessary for application of this model</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Studies of neurorepair, neuroplasticity, angiogenesis, etc. requiring medium- or long-term monitoring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
develop very small infarction sizes, and the Sprague Dawley (SD) strain. Problems have been detected in the SDOFA sub-strain with regard to the variability between batches affecting the size of the infarction.

The importance of the use of mice is determined by the use of genetically modified animals. The specific use of a particular strain is not recommended, although it is important to remember that the volume of cortical infarction may vary enormously between strains. For example, the infarction in FVB mice may be up to three times smaller than in BALB/C mice.

With respect to sex, the recommendation is to replicate the study in a particular group using the other sex and to evaluate at least the main end-point of the study. This recommendation is aimed basically at works designed to establish the therapeutic effect of an agent.

On the other hand, our groups have used young adult animals (250-350 g in rats; 812 weeks in mice, 2530 g) for the study of cerebral ischaemia. For the study of ictus risk factors streptococci was applied in the case of diabetes, while for hypertension spontaneously hypertensive rats (SHR) should be used or the “2K1c” model should be contemplated for the induction of hypertension.12

**Realization of the experimental design**

The preparation of the experimental design prior to the execution of the study is essential for the correct development of the models. The points described below must be considered in the experimental design:

**Experimental study groups**

The realization of a sham control group will be included in the experiment. In addition, the use of old controls for the comparison of results should be avoided and, where appropriate, a control group of animals should be used to confirm that the study end-points are reproducible between the old animals and the new ones operated on.

**Sample size**

It is recommended to calculate the sample size for use in each study (using a 1 β power of 0.8 and a level of significance α of 0.05). Once the exclusion criteria have been applied, there must be at least n = 10 valid animals in each experimental group.

**Randomization**

The allocation of each animal to an experimental group will always be done on the basis of a random choice, and the use of computer software is recommended.

**Blinding of the allocation during the experimental process**

It is recommended that the researcher responsible for inducing the ischaemia/reperfusion and for taking decisions on the end-point criteria should be unaware of the experimental group the animal belongs to.

**Blinding of treatment**

It is advisable for the administration of treatment by a researcher to be done blind. In order to achieve this goal, the use of treatment encoding strategies is proposed.

**Blind evaluation and analysis of the study variables**

It has been established that, when assessing the various study parameters (for instance, infarction volume, neurological deficit, ...), the researcher in charge of conducting this assessment should not know the treatment group the study subject belongs to.

**Inclusion and exclusion criteria**

It is of significant importance to define these prior to starting the study. It is established that each group will take this decision with regard to the definition of these criteria (for example, the exclusion of animals that fail to develop a minimum size of ischaemic lesion or a minimum score in the neurological deficit analysis).

**Registration of variables in the preparation of the models**

The measurement of cerebral perfusion in the region irrigated by the MCA using Doppler laser flow metering must unavoidably be performed when using cerebral ischaemia models to ensure the occlusion and reperfusion of the artery and to corroborate the success of the operation. In addition, its use is recommended in permanent models to confirm homogeneous occlusion. The cerebral flow thresholds established for considering occlusion and reperfusion of the MCA to be acceptable are indicated in table 2, and these should be treated as inclusion/exclusion criteria.

**Anaesthesia and analgesia**

It is advised to replace the use of inhaled anaesthesia using isoflurane by sevoflurane. For analgesic treatment, magnesium metamizole is recommended, and notice must always be given of which drug has been used.

**Stabulation conditions**

Twelve-hour light and dark cycles must be used and the animals must be kept in a controlled environment with optimal temperature (22°C) and humidity (50%). The network has experience with the differences that dietary composition may entail for some experiments, so it is recommended to feed animals with a known diet and to ensure water is freely available. Suspending food the day prior to surgery is something most of our groups do not do. The possibility of determining glycaemia prior to performing the surgical procedure should also be taken into account.

**Notification**

All the aspects contemplated in the preceding paragraphs will be notified in the publications arising out of a study. In addition, notice must be strictly provided for the mortality rate in the study together with the number of animals excluded and why.
Evaluation of the study parameters, expression of the outcomes and statistical applications: infarction size and neurological assessment

To avoid variability, it is desirable for the various analyses and procedures for the assessment of these parameters to be conducted by the same person insofar as this is possible. The calculation of the infarction volume must also be made taking into account the correction for cerebral oedema and it is recommended to calculate and express the result in terms of cortical infarction and striate or sub-cortical infarction separately, as well as the total volume infarcted.

The authors feel that there are currently no adequate neurological tests. Of those available and depending on the study phase, it is recommended to use the Bederson test or tests based on the Bederson test (for example, a 09 scale) for studies of neuroprotection in the acute phase and to assess the possibility of performing functional tests in the short term. For chronic phase studies (neurorepair studies), it is recommended to try out neurological scales (for example, the Bederson test) and to perform functional tests; the Corner test and Sticky Label tests are advised.

The functional tests must be evaluated at the same time of day for all animals in the study.

With respect to the expression of the data obtained, the recommendation is that, in the case of those with a normal distribution, they should be reflected as mean ± standard deviation or by providing the 95% confidence interval; for non-normal datasets, it is advisable to use the median and the interquartile range. In either case, a check must be made that the distribution is normal before using parametric statistical tests. On the other hand, it is recommended that the graphic representation of the infarction volume should also be given in a bar chart, using representation by points, so as to be able to observe the individual values of each animal.

Conclusions

One of the most important causes of bias in clinical evidence on the efficiency of neuroprotective strategies in the experimental study of ictus lies in the design, methodology and notification of results when using animal models. In order to ensure translational success in the advance of stroke treatment, effectively reduce the number of animals used and avoid unnecessary financial expense, teamwork is required in the scientific community. It is essential to undertake methodological commitments for the optimization of the use of cerebral ischaemia animal models so as to increase the yield of positive findings in the field of science. Following the recommendations set out in this guide, such as the choice of a suitable model, monitoring temperatures, measuring cerebral blood flow using Doppler laser flow meters and the notification of the mortality rate when publishing the results, will improve the quality of the studies and generate extremely useful pre-clinical findings that can then be put into practice in the clinical setting.

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Conflicts of interest

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