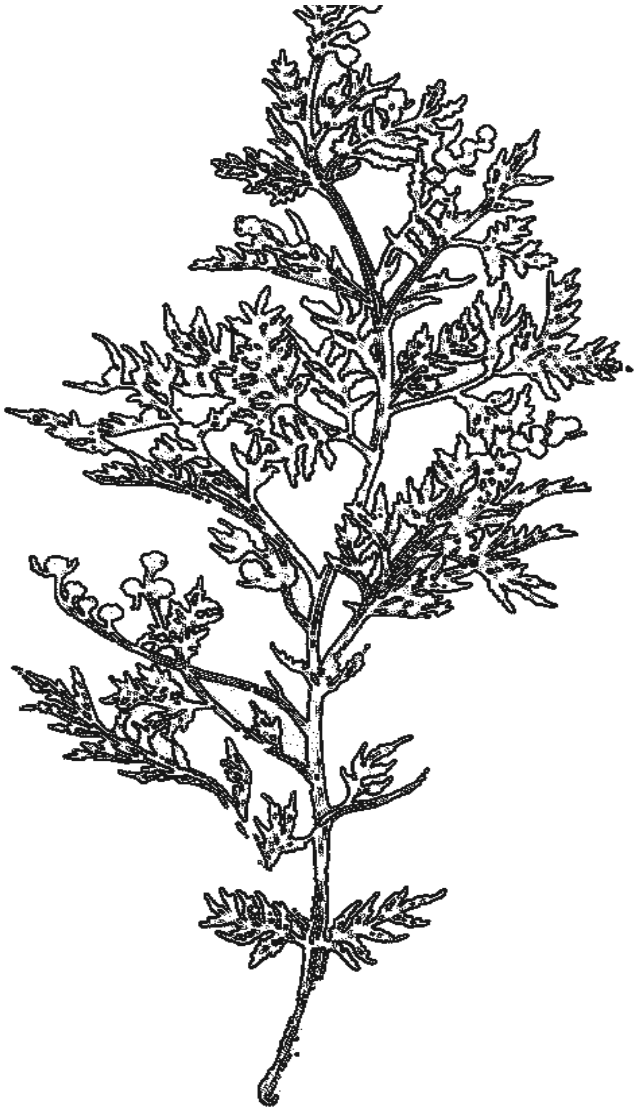
TDR/TDF/99.1

WHO Informal Consultation on clinical neurological investigations required for patients treated with artemisinin compounds and derivatives



Report of an Informal Consultation convened by WHO

Geneva 20 July 1998

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20 July 1998, WHO/HQ Geneva

Statement of Issues

Several compounds of the artemisinin family are being developed for the treatment of severe malaria, including dihydroartemisinin (DQHS), artemether (AM) and artesunate (AS). So far they have proved to be effective in man and to have caused few adverse effects in clinical use.

Recent experimental studies at the Walter Reed Army Institute of Research have showed that the more lipophilic artemisinin derivatives were able to produce a unique pattern of sparse, selective neuropathy in the brainstem in animals given very high parenteral doses over a short period. The ranking of susceptibility of the species examined is dog>rat>rhesus monkey. Although the pharmacokinetics of the compounds in these animals has not been characterized completely, the doses required to produce the neuropathological changes have been several-fold higher than therapeutic doses in man. [1] [2] [3] [4][IRR1] [5] [6] [IRR2]

There is persistent neurological deficit following cerebral malaria in 3% of adults and 10% of children. In a very large number of clinical studies, some of which have included detailed neurological examinations and long-term follow up, there has been no evidence of neurological damage in patients treated with any of the compounds, not even in cases of cerebral malaria. Children have also been shown to develop normally after treatment in studies that have included specific investigations of neurobehavioural development.[7] [8] [9] [10] [11]

Because of concern about the possible risk of neurotoxicity, a WHO Informal Consultation was arranged to review and outline appropriate future clinical studies to rule out neurotoxicity in man. The specific objective of the consultation with neurology and other experts was to plan appropriate strategies for investigations at the bedside and in more sophisticated facilities.

Professor Dayan opened the meeting by stating that neurotoxicity has been seen in a number of animal studies with high dose, parenteral administration of lipid-soluble artemisinin (AMS) derivatives, but not after oral administration. It is considered that water soluble compounds (e.g. artesunate) are generally less toxic and have not been shown to produce neurotoxicity in animal experiments. There is no single, typical neurological syndrome that characterizes the terminal stages of AMS toxicity in animal studies. Neuronal damage was characterized by chromatolysis and necrosis of a few scattered neurons in certain brainstem and cerebellar roof nuclei.

Clinical perspective of the role of AMS derivatives and a description of cerebral malaria

Professor White and Dr Hien provided background information from a clinical perspective. Artemisinin derivatives (based on the DHQS structure) were developed in China in the early 1980s. Therapy with artemisinin derivatives was introduced in Viet Nam in 1989, when 1 million cases and 3-4000 malaria deaths occurred each year. A double blind study conducted between 1993 and 1996 in the Centre for Tropical Diseases, Ho Chi Minh City, compared intramuscular artemether (AM) and quinine (QN) in adults with severe malaria. This study showed a decreased parasite clearance time (PCT), but prolonged fever clearance time (FCT) and coma recovery and also a slightly (but

non-significantly) lower mortality in the AM arm.[12] No adverse effects were found in assessments, which included frequent, thorough neurological evaluations, electrocardiograms and audiometry. Results of blinded post-mortem examination of brainstems from this study are pending (preliminary results show no gross abnormalities). Since use of artemisinin and its derivatives as standard treatment was implemented in Viet Nam, fewer falciparum malaria cases and fewer malaria deaths (>3000 deaths in 1989 - 150 in 1997) have been recorded.

Cerebral malaria has a 15% mortality (despite adequate facilities and treatment), with approximately 10% of surviving children having a detectable neurological deficit, and occurs predominantly in areas of low to intermediate malaria transmission.

Millions have been treated with the AMS derivatives in South East Asia especially, and increasingly in South America and Africa; 10 - 20 000 of these patients have been followed and fully documented in prospective studies. A TDR/Wellcome Trust study in Viet Nam, which recorded AMS dose and conducted audiometry and measured auditory evoked potentials (analysis blinded), found no difference between controls (who had never received AMS) and cases. This study was repeated in Thailand, with 80 patients who had had 2 or more treatment courses. An additional 1100 cases in Thailand have had full neurological examinations, performed by physician assistants. No specific pattern of neurological abnormalities was seen in these patients. In the comprehensive clinical examinations, the only relevant condition that might have been missed because of training of the examiners was fine abnormalities of eye movements.

General discussion and questions

Q: What is the nature of residual deficit observed in children with a history of cerebral malaria?
Prof. White replied that these are predominantly ischaemic strokes, hemiplegia, cortical blindness or global deficits; less common are tremor, isolated cranial nerve palsy, or psychosis. Deafness has not been described. The natural history of the obvious residual neurological deficit is that 75% recover in one year. Subtle psychomotor abnormalities may persist. Cerebellar dysfunction also occurs and is thought to be malaria related.

Q: Was the post malarial syndrome described in US veterans after service in Viet Nam (which responds to steroids and so may be immune related) seen in the Viet Nam RCT?
Dr Hien replied that children who have received up to 14-15 AM doses were assessed, including Auditory Evoked Potentials (AEP), and no abnormality was found. Dr Ribeiro and Professor White added that adverse event data on 11 400 cases (1400 of whom had serial detailed neurological examinations, 600 of which were published), had been collected and no significant neurological damage had been identified.

Q: The Vardi study showed abnormality of higher cortical function - is this part of malaria?
In Kilifi, a 5-year follow-up included psychometric and higher function tests - unpublished results suggest borderline possibility of abnormalities.

Q: What about quinine neurotoxicity (QN)?
Prof. White replied that QN is cochlear poison. Dose-related reversible hearing impairment occurs in high doses. Permanent blindness (now believed to be a direct toxic effect on the retina) is well described with standard doses. It was once attributed to the retinal artery spasm. It also occurs in overdose. QN also causes hypoglycaemia by inducing hyperinsulinaemia and may thus cause neuronal damage indirectly.

Discussion of sites where special neurological studies might be carried out

Ghana site (Dr Binka):
Dr Binka described an area in Navrongo with hyperendemic malaria (mean EIR 300/year, seasonal), with 140 000 people in dispersed settlement over 1600 km^2, underutilized health facilities and the district hospital (2 physicians) seeing more cases than health centres, and where only gross neurological signs are noted, diagnosis is clinical, and health services are basic. Nine hundred severe malaria cases are admitted/year. The bulk of cerebral malaria patients go to traditional healers.

CDC / KEMRI, Kisumu, Kenya (Dr ter Kuile):
Dr ter Kuile described an area with intense perennial transmission and high-grade chloroquine (CQ) resistance. This centre is currently involved with:

- Hospital based studies (on the overlap of malaria and HIV in pregnancy);
- Laboratory based studies;
- Large community based studies on the effect of insecticide impregnated bednets on under-5 mortality, which is being conducted over 200 km^2 in a population of 120 000 (in 200 clusters). The strength of the community-based studies is in numbers, but no system is in place to conduct a detailed neurological examination. Severe malaria presents predominantly as severe anaemia - cerebral malaria is not common.

Wellcome Trust Centre, Viet Nam (Dr Hien):
Dr Hien described an isolated area with 2- 4000 inhabitants, which is poor, and with limited access to drugs. A community health station is established and a team could be sent to regularly assess patients.

Wellcome Trust Centre, Malawi (Prof. Molyneux):
Blantyre is in an area of lower transmission (with more cerebral malaria) and this centre is based in an academic hospital. Several hundred cerebral malaria cases are seen each year, and a plan to introduce magnetic resonance imaging (MRI) and computed tomography (CT) facilities in the private sector shortly has been proposed.

Discussion of appropriate methods and investigations

Two questions were addressed in this discussion, namely:

- A study to be designed specifically to exclude / define neurotoxicity in humans
- Defining what neurological assessment should be conducted in Phase 4 studies to be carried out by WHO and other pharmaceutical companies taking any one of these derivatives to registration.

The clinical investigations would be directed at the functions controlled by the specific areas in the brainstem known to be affected in animal experiments.

Professor Thomas recommended that hearing, vestibular function, RAS (alertness), and cerebellar function (control of voluntary movement) should be assessed by:

- Clinical history and examination
- Level of consciousness (LOC)(Glasgow Coma Scale)
- MiniMental test [standardized for the local population]

- Speech, tongue - twister, repetitive sounds [appropriate to local language]
- Eye movement control (sophisticated ocular motility tests at tertiary medical centres) - pursuit movements (saccadic intrusions), nystagmus, saccades (latency of onset, speed of movement, fluency to be conducted at tertiary centres as part of more sophisticated evaluation), vestibular - ocular movements (fixation is maintained while head is passively moved), optico-kinetic nystagmus (rotating drum)
- Hearing a whispered voice at 2 feet [0.6m], tuning fork
- Hallpike-Dix manoeuvre (central lesions characterized as non-fatiguing as opposed to labyrinthine pathology)
- Postural maintenance, postural tremor, finger nose test, misjudging of distance (dysmetria)
- Repetitive movements (tapping, dysdiadochokinesis, pinch grip, heel-to-shin test, tapping foot)
- Gait (unsteady, tandem walking)
- Postural reflexes – capacity to regain standing posture when pushed

The meeting also felt that it was important to keep assessment simple, using a validated examination e.g. modified Adelaide scale (obey command, localize to pain, verbal, eye response), or Blantyre Coma Scale (motor and verbal responses to pain, ability to look). It was admitted, however, that these examinations, given the extent of the lesions, might not be sufficiently detailed or sensitive enough.

Given the large numbers of patients who have had clinical and auditory assessment following treatment with this group of drugs, without any evidence of neurotoxicity, the group focused on what additional studies were necessary to exclude neurotoxicity in man.

The principles for assessing the potential neurotoxicity of the group of drugs included:

- The significant role of a thorough clinical history (e.g. coordination and balance disorders can be readily detected by a functional history).
- There is a need for a detailed neurological examination, as the damage in animal studies occurs in small areas of brainstem, and limited brainstem and cerebellar dysfunction might otherwise be missed
- This effect is not idiosyncratic, but dose-related, so a detailed assessment should be focused on those patients most at risk (believed to be those exposed repeatedly or at high doses to lipophilic compounds, such as AE, AM, DQHS).
- As neurological abnormalities occur anyway after severe malaria, it might be best to study uncomplicated cases, although Prof. Molyneux pointed out that the risk of toxicity might be greater in severe malaria, as infected red blood cells concentrate DHQS 300-fold, and Prof. Milhous raised the possibility of a parasite burden effect.
- Timing of examination during clinical studies will be important as the effect seen in animal experiments has usually been apparent between 3 – 7 days after dosing. Although neuronal necrosis is permanent, patients may compensate for neurological deficit over time. Auditory and vestibular assessment are considered especially necessary given the site of the animal lesions.
- Higher cortical functions should be assessed, as diffuse or minor abnormalities may lead to abnormality in higher function.
- Prof. Folb commented that new animal studies would be of little investigative value at this stage, as they are removed from clinical experience and a pharmacokinetically comparable model was not available.

In terms of detailed assessment at specialist centres, the following investigations were mentioned:

- Enolase in the CSF, which is a specific marker of neuronal necrosis, might be assayed if CSF were available. The ethics and feasibility of doing lumbar punctures in cases of uncomplicated malaria were questioned.
- The quantitative caloric test with monitoring by ocular vestibulography might be assessed.
- MRI (magnetic resonance imaging) to look at size of inferior olive; PET (positron emission tomography) scanning (glucose utilization), MIS, MRS (magnetic resonance spectroscopy) also mentioned. A specialist MRI radiologist should be consulted regarding the potential usefulness of special radiography, and to define level of resolution, whether enhancement is necessary and whether various MRI signal enhancement protocols might be helpful. These would require a specific objective; in brainstem nuclei investigations, the sensitivity of these techniques is not likely to be sufficient to identify the apparently small lesions in the brainstem.

It was suggested that such specialist investigations might first be validated in animals, as the inferior olive nucleus might be too small for the effects of limited chromatolysis and sparse single cell necrosis to be seen. If no abnormality can be detected in animals shown to have the most severe histopathological changes, then the techniques are unlikely to be helpful in patients with no or minor neurological defects.

From a drug regulatory perspective it was felt that:

- Drug surveillance should be continued throughout future studies, using only simple bedside tests (with the possibility of video recording of eye movements in a subgroup of patients for subsequent, more detailed assessment)
- Specialized detailed studies (MRI, enolase assay) may be necessary to increase confidence when the drugs are to be widely deployed, provided that they have been shown to be capable of giving sufficient sensitivity.

Q: What is the minimum, therapeutic plasma drug concentration for this group?
Prof. White stated that a recent study indicated that the lowest mean dose of oral artesunate giving maximal effect on parasite clearance was 2 mg/kg. Therefore, given the large inter-patient variability in kinetics, it would be prudent to keep at least initial doses above this (i.e. 4 mg/kg).

Artesunate Phase IV Field Trials

The rural setting, age of patients, and danger of generating invalid data should be borne in mind as requirements for surveillance for possible neurotoxicity during Phase IV artesunate field studies. Dr Ribeiro described the Phase 4 Study Design: i.e. rural, village level, randomized placebo-controlled clinical trial with individual/cluster randomisation, clinical diagnosis of malaria plus ‘nil per os’, with all patients referred to hospital for completion of treatment. Examination would occur at baseline, admission, discharge, early and late (6 - 12 months) follow-up. Dr Ribeiro and Dr Yatsu proposed that the following be monitored:

- At village level: level of consciousness (LOC) (alert / obtunded / comatose) could be evaluated by the village health worker by assessment of verbal response and pain localization (call name, yell and pinch).

- At hospital level:
  - LOC (modified Adelaide or Blantyre Coma scale)
  - Mental status (memory)
  - Cranial nerves (follow finger in round circle, hearing the rapid rubbing of fingers)
  - Motor (raise arm)
  - Coordination and balance (walking in straight line)

  Limited examination in infants - except for LOC, and questions to mother, such as "Is the child acting the same?"

The group was aware of possible confounding by pre-exposure, and concomitant management although it was assumed that randomization would distribute confounders evenly. Extensive discussion of which methods and investigations were appropriate was concluded by the neurologists agreeing to prepare a consensus recommendation, for inclusion in the Phase 4 Case Record Form (Appendix 1).

Retrospective studies

The following were recommended for re-assessing patients included in earlier (AM / AE) studies:

- Full history
- Full examination
- Psychometric test, appropriate for community
- Video records of eye movements in children aged over 3 years
- Audiometry
- Sound lateralization with click stimuli
- AEP
- Best available scanning [not CT scans as radiation dose not justifiable]

Although this study was considered feasible (in Malawi, Thailand and Viet Nam) it would be important to avoid selection bias which occurs over time if there has been significant loss to follow up, and with compensation of any neurological deficit with time. This would dilute information gleaned.

Prospective Studies

Given the limitations of the above studies prospective investigations in specialised centres were also recommended. In such studies 20 patients might be followed in detail, using similar neurological assessment methodology as in the retrospective studies described above. To look for a class effect, this type of study should look at AM / AE-treated patients *and* controls.

Information Exchange

Dr Lugt recommended that the group should review the AE file, with the permission of WHO. Dr Gomes reassured the group that WHO/TDR had approached potential neurotoxicity as a class issue, had reviewed the AE file and encouraged exchange of information between all parties involved in the development and use of this class of compounds for the treatment of malaria.

Dr Dayan closed the meeting by summarizing these recommendations and thanking the participants.

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DISCHARGE FORM

Appendix 1

Date of discharge …../…../…..
Dd/mm/yy

Study adm. Time …./…/…
e.g. 13:47

Date of admission …../…./…..

Outcome ❑ Survived ❑ Died

Treatment to go home
❑Off medications ❑Iron ❑Other
❑Quinine ❑Folate ❑ Paracetamol
❑Sulphadoxine-pyrimethamine

Does the patient has any new problems with the following?

Feeding ❑Yes ❑No ❑NK

Walking ❑Yes ❑No ❑NK

Talking ❑Yes ❑No ❑NK

Sitting ❑Yes ❑No ❑NK

Sight ❑Yes ❑No ❑NK

Hearing ❑Yes ❑No ❑NK

Playing ❑Yes ❑No ❑NK

Balance ❑Yes ❑No ❑NK

Behaviour ❑Yes ❑No ❑NK

If answered "yes" to any of the above questions, please specify ……
……
……

Pulse …….. SBP……. Weight at discharge ……kg
Temperature axillary ……

Response to painful stimulus (Blantyre Coma Score) Best=5

Eye movements
❑ 1 Not directed
❑ 2 Directed

Verbal response
❑ 0 None
❑ 1 Moan or inappropriate cry
❑ 2 Appropriate cry

Best motor response ❑ 0 Non-specific or absent response
❑ 1 Withdraws limb from pain
❑ 2 Localises painful stimulus

TOTAL:…….

Ability to follow a circle (with both eyes)
❑Normal ❑Abnormal ❑ Too young to perform task
❑Uncooperative with exam

Nystagmus
❑Present ❑Absent ❑ Too young to perform task
❑Uncooperative with exam

Ability to hear the rapid rubbing of fingers (within 2 in or 5 cm from both years)
❑Normal ❑Abnormal ❑ Too young to perform task
❑Uncooperative with exam

If abnormal, please specify ……
……

Speech ❑Normal ❑Abnormal ❑Not yet speaking ❑Uncooperative with exam

If abnormal, please specify……
……
……..

Ability to raise both arms ❑Normal ❑Abnormal ❑ Too young to perform task ❑Uncooperative with exam

Does the child walk steadily? ❑Yes ❑No ❑ Too young to perform task ❑Uncooperative with exam

Heel-toe walking ❑ Normal ❑Abnormal ❑ Too young to perform task ❑Uncooperative with exam

If abnormal, please specify……
……

Romberg ❑Present ❑Absent ❑ Too young to perform task ❑Uncooperative with exam

Picking tablets ❑Normal ❑Abnormal ❑Too young to perform task ❑Uncooperative with exam

Pencil touching ❑Normal ❑Abnormal ❑Too young to perform task ❑Uncooperative with exam

Rapid hand tapping ❑Normal ❑Abnormal ❑Too young to perform task ❑Uncooperative with exam

Drawing a spiral ❑Normal ❑Abnormal ❑Too young to perform task ❑Uncooperative with exam

If abnormal, please specify……
……
……..

Fever clearance time (=time in hours till axillary temperature falls below 37C
And remains below 37C for 2 subsequent 4 hourly readings) …….hrs

Parasite clearance time (=time in hours till the first of 2 consecutive negative
blood films) …….hrs

When did the patient become able to:

Eat at …….:…… (e.g13:47) on (date dd/mm/yy) …../…../…..
Drink at …….:……(e.g.13:47) on (date dd/mm/yy) …./…./…….

Follow-up arranged? ❑ Yes ❑No
Date of follow-up …../…../…….

Time of death…..:…..
Date of death …../…../….

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