



Expert commentary on the age assessment of John Ndollu prepared for Fisher Dore Lawyers, Brisbane, Australia.

By Sir Albert Aynsley-Green Kt.

MA, MB.BS, D.Phil, Dhc, D.Univ, DCL(Hon), MD(Hon)
FRCP(London and Edinburgh), FRCPCH, FMedSci, FRSA, FFPH(Hon)

Professor Emeritus of Child Health,
University College London;
Director, Aynsley-Green Consulting;
Former Children's Commissioner for England.

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Contact: al@aynsley-green.com

Professional background and relevant experience.

My career in medicine began at Guy's Hospital in London before training as a specialist in paediatric endocrinology (the science of normal and abnormal secretion of hormones in childhood) in University hospitals in Oxford, England and Zurich, Switzerland.

I was Clinical and then University Lecturer in Paediatrics and Fellow of Green College at the University of Oxford, before being appointed James Spence Professor of Child Health and also Head of the School of Clinical Medical Sciences at the University of Newcastle upon Tyne. I then became Nuffield Professor of Child Health and Board level Executive Director for Clinical Research & Development at Great Ormond Street Hospital for Children and the Institute of Child Health in London.

I have been involved in the political arena of Children's Services since 2000. I was Chair of the first NHS Children's Task Force, and first National Clinical Director for Children in the Department of Health where I was responsible for producing the first National Standards for children's health services. I was appointed to be the first Children's Commissioner for England in 2005, stepping down after my five years of tenure in 2010.

I am now Professor Emeritus of Child Health, University College London, Honorary Fellow of UNICEF and Oriel College, University of Oxford, and Director, Aynsley-Green Consulting, acting as an advisor to governments and institutions in Europe, Australia and Canada on children's services and childhood.

I was knighted for my services to children and young people by Her Majesty the Queen in 2006, and have received many national and international indicators of esteem.

This commentary is informed by my professional training and over 30 years of clinical experience as a children's physician, specialist in paediatric endocrinology. I have been responsible for regional specialist endocrine and growth clinics for children in Oxford and Newcastle upon Tyne, and for national and international patient referrals in Great Ormond Street Hospital for Children in London.

I have been Secretary General and President of the European Society for Paediatric Endocrinology, the leading international forum for such specialists, and the recipient of the Andrea Prader Prize of the Society, this being the highest award for leadership and contributions to the subject offered internationally to a specialist in the discipline.

As the first Children's Commissioner for England I led major inquiries into the circumstances of children and families seeking asylum in England, and my reports have led to significant changes in government policy, especially on the screening process, and the arrest, detention and deportation of failed asylum seeking families. My reports were grounded in the unique statutory power given to me by Parliament to enter any premises, unannounced if necessary, other than a child's home, and to interview any child and in private if the child agreed.

I was a member of an Expert Working Party set up by the previous UK government to examine the practice of age assessment in the UK, arguing in particular that X-rays should not be used as an assessment tool.

In the last year alone I have been invited three times to Norway to meetings arranged by the Norwegian Ombudsman for Children and then the Norwegian Immigration Directorate to give evidence in its Government's proposals for the practice of age assessment. I also gave evidence in December 2010 in events in Brussels organised by the Belgian Presidency of the EU and then the General Assembly of the European Paediatric Association, following which I was commissioned in January 2011 by the Office of the Spanish Ombudsman to prepare a comprehensive report on the assessment of age in undocumented migrants, and this was published in March 2011.

I have now been invited by Fisher Dore Lawyers in Brisbane, to offer specific expert commentary on the circumstances of John Ndullo, and also to prepare a detailed overarching and comprehensive report on age assessment which should be read in parallel in order to provide a context for the comments I make on the case.

The facts of the case of John Ndollu

I have read the evidence given to me which includes the:

- Statement of Facts prepared by Federal Agent Nolan Wynne,
- Extract of Birth Certificate taken from the Statutory Civil Registry in Indonesia which confirms his date of birth to be the 29th July, 1994
- The age assessment performed by Mr Todd Jacob for the Australian Department of Immigration and Citizenship which used a formal protocol for evaluation. He concluded from the interview that the subject was under the age of 18.
- Affidavits from the subject's mother and others confirming from photographs that the subject is John Ndullo, and that he is under 18 years old, consistent with the birth certificate
- Opinion from Dr Chris Whisson, Northern Territory Medical Imaging, Mitchell Street Darwin, on an X-ray of the Left hand and wrist performed on 21st May 2010 authorised by the Australian Police, in which he concludes '*The growth plates are all fused and the bones fully developed. By the standards of Greulich and Pyle the bone age is not less than 19 years*'.
- Two opinions dated 20th April 2010 and 11th May 2010 from Dr Vincent Hock Seng Low, consultant radiologist, who concludes from examination of the same X-ray of the Left Wrist by the Greulich and Pyle method that the subject had attained skeletal maturity and was therefore probably 19 years or older when the X-ray was taken. He offers an interpretation that there is a 76% probability of him being greater than 18, with a 24% probability of being less than 18. It is relevant to say that there are inconsistencies in Dr Low's reports. Thus, the X-ray date used in paragraph 2 of page 3 of both reports is different from the X-ray date used in paragraph 3 of the same pages, ie, 21st May changed to 26th April 2010. Moreover, and of considerable importance, on page 3 of the report of the 20th April he suggests that there is a 1:2000

chance that the subject was born on the claimed date; that figure is revised downwards to 1:200 in the corresponding paragraph of the report of the 11th May. Likewise the table on page 4 of the 20th April report is revised in the 11th May report. There is no explanation for these changes, but taken together, a question has to be raised about the reliability of Dr Low's evidence.

- Copy of the authorisation by Mr C Jessop, Australian Federal Police dated 21.05.10 for the X-ray to be performed on the grounds that the subject may have committed a Commonwealth offence. This is accompanied by a signed consent from an independent observer, Ms C Collier, and a document with a signature from a John Ndolu (NB different spellings of his name occur in other documents) that is not in the English language. A translation into English has not been provided, and so it is not possible to know with certainty that the subject had fully understood the purpose of the X-ray and the implications that might follow from the result. Whether the documentation confirms the principle of full informed consent has to be challenged

I am led to understand that despite the evidence from record of birth, certified affidavits and age assessment by interview that he is under the age of 18, it is on the basis of the radiologists' opinions that the subject has been judged to be adult. As a consequence he has been incarcerated in an adult detention environment, although I believe he is currently on bail, pending the conclusion of the forthcoming court process.

Key issues arising from the evidence:

1. Why have the Prosecution Service and the Police over-ridden the weight of documentary evidence from Indonesia and the age assessment performed by the Australian Government's own Department of Immigration and Citizenship that the subject is a Juvenile?
2. If the basis for the action is the reports on the skeletal X-ray, is the method of Greulich and Pyle appropriate, accurate and reliable?
3. Is the conclusion by Dr Whisson correct that the growth plates have fused and that by the standards of Greulich and Pyle the bone age is not less than 19 years?
4. Is the conclusion of age and the probabilities proposed by Dr Low valid?
5. Is it proper for such a key decision of age to be taken on the basis of one X-ray examination alone?
6. Was full informed consent obtained for the X-ray to be performed, and is there clear evidence that the subject understood the purpose and possible sequelae that would follow the result?

Since the outcome of this case depends on the appropriateness, reliability and certainty of the interpretation of the X-ray and its inference for chronological age, the following paragraphs focus on the place of radiology in the assessment of age of migrants, and are then set in the context of current debate internationally.

The 'science' of radiology is highly attractive to government and agencies because of the aura that it will give a precise 'scientific' result. But its use is fraught with difficulties, and these must be spelled out to government and officials and to Courts when age is disputed.

In the author's view radiology for age assessment is unethical, inaccurate, not fit for purpose proposed, and potentially unlawful.

First, imaging of bones or teeth can *NEVER* tell precisely the chronological *age* of the individual. All it can do is to provide an estimate of the degree of *maturity* the person has experienced when compared to images from control subjects, and within the very substantial range of normal development during adolescence. The methods used were not designed to assess disputed chronological age – they were prepared for medical use in diagnosis and the monitoring of disorders of growth.

Second, it should, in the ideal world, be performed by a comparative assessment of the image of the individual against standards of normality for the population from which the person comes. Such standards for children from many countries in Asia, Africa or the Middle East are not available, and it is unsatisfactory, not least because of the influences of nutrition or disease to assess their images from standards derived from healthy Caucasian, European or North American standards. Even when comparative normative images exist, at best chronological age correlates to +/- 2 years of maturity age. In some entirely normal children this may be discordant for as much as 4-5 years (see below).

Third, although superficially easy to do (and inexpensive), it demands expert interpretation by experienced paediatricians, dentists or radiologists.

Fourth, radiology inflicts a radiation dose which, for age assessment of undocumented migrants, is driven solely **by government's administrative convenience and without therapeutic benefit to the individual.**

This is a different circumstance to the routine X-raying of the chest designed to detect tuberculosis. This disease is of serious importance to the individual and to the public health of the nation. This is not the case for radiology for administrative purposes which does not confer therapeutic benefit, and raises profound ethical objections to its use.

Fifth, such estimations should only be performed with the full and documented informed consent of the individual. Performing such studies without such consent is, in the UK at least, unlawful, and could lead to practitioners so doing facing legal charges of assault and professional misconduct.

Because of the concerns that such methods are inaccurate, unethical and potentially unlawful, **every** relevant statutory and professional body in the UK, including medical Royal Colleges, supports the view that radiology should not be used for the

administrative purpose of age determination. Because of the weight of expert opinion, the UK Government does not promote the use of X-rays for age assessment. This position was reiterated in a House of Lords Debate in London as recently as March 2011 by Lord West, the Government Minister who stated '*...it was absolutely agreed not to do so (ie take X-rays). There is no intention for us now to do that*'

This robust position is further supported by the British Society for Paediatric Endocrinology whilst the Council of European Society for Paediatric Endocrinology (the leading and largest international forum for such specialists) stated in 2007 that '*ESPE Council's position is that dental and skeletal maturity cannot be used for assessment of chronological age*'

Moreover, the International Olympic Committee and FIFA have also agreed that for the same reasons but in a very different context, ie Sports Medicine, radiology should not be used to assess age of young athletes, a stance supported by the World Health Organisation and international atomic energy authorities.

Even though the radiation dose from an X-ray of the hand is small (equivalent to 0.00017mSv ie one hour exposure to background radiation in many cities), in the author's opinion, it is not acceptable for radiologists, dentists and others to say that 'It's only a little bit of radiation that will do no harm!' The recent events in Japan following the March 2011 earthquake and nuclear disaster have re-emphasised the potential risks from any amount of unnecessary radiation.

The assessment of skeletal maturity using the atlas method of Greulich and Pyle.

This atlas of bone development in the left hand and wrist was published in the 1950s by two American authors using X-rays from 1000 largely white middle class American children born in the 1930s. The atlas builds on earlier work by Todd and others, and comprises a series of pages with a representative X-ray from a single child of known age on each. The usual practice is for the radiologist to take the X-ray from the individual being assessed and turns the pages to find the X-ray which most closely corresponds to it. The chronological age of the child in the atlas radiograph is then given to the individual's X-ray.

Growth takes place at the ends of each long bone where there is an ossification centre with a growth plate or epiphysis of soft bone (cartilage). As the child's wrist develops, sequential changes occur in the amount of bone being laid down in the cartilages of the wrist and finger bones (the white substances in the images), and sex hormones during adolescence lead to deposition of bone in the growth plates. This leads to 'epiphyseal closure' after which no further growth can occur, the bones being fully mature. If there is clear evidence of linear growth from measuring a child's

height sequentially, then the epiphyses cannot be closed and therefore the individual is not fully mature.

The method is highly subjective with the potential for considerable inter-observer range of 'ages' given by different radiologists; furthermore, the X-rays are not derived from contemporaneous children, but reflect the speed of bone development over 70 years ago. Important secular changes have occurred in an acceleration of the rate of sexual development and hence attainment of skeletal maturity since then. Expressed succinctly, children are developing earlier than in the 1920s and 30s, and this is reflected in earlier skeletal maturity. Finally, it is not known from where in the range of normal bone development the single reference standard at each age lies – it could have been taken from a 'late' or 'early' developing child from families with a genetic predisposition to early or late physical development.

Whilst other bones are also often assessed, for example the clavicle or elbow, the X-ray of the left hand remains that most commonly used.

Dr Low asserts that '*There has not been any professional recognition of a need to re-assess the standards through fresh studies, because radiologists world-wide have not perceived any significant changes in the rate of skeletal development*' and '*therefore the findings of Greulich and Pyle from over 50 years ago remain relevant today*'. In my opinion he is wrong in both statements (see below).

Thus, recognising the thoroughly unsatisfactory basis of the Greulich and Pyle atlas method for clinical use that demands precision, and in an attempt to improve both the reliability and precision of the radiological approach, Tanner and Whitehouse introduced a more complex process in 1962, the TW2 method. In this approach, every one of the 20 bones of the hand and wrist is scored against pictorial and written criteria derived from 2700 British lower and middle class children's X-rays. The total score is calculated and then entered into percentile charts similar to growth charts. The method was updated to produce the TW3 data that reflect the secular changes in earlier adolescent development that Dr Low appears to be unaware of. The TW method is the one my colleagues and I used routinely in our specialist endocrine clinics in Oxford, Newcastle upon Tyne and in London, even though it is much more time consuming to perform than the Greulich and Pyle method

The TW method still inflicts a dose of radiation although it does reduce inter-observer variability.

The figures below shows the 20 bones of the hand and wrist that are assessed, and percentile charts showing the range of scores for assessment against each age for boys and girls.

Thus, the observer, rather than making a superficial assessment as in the Greulich and Pyle method, 'rates' each bone in the subject's X-ray against rigorous written

and pictorial criteria; the total score is then calculated by summing the individual scores (vertical axis) and entered onto the chart against the child's age (horizontal axis). A score of 100 in the TW2 method indicates complete bone maturity, and it can be seen that for boys, 50% of normal boys will have achieved 'adult' appearances by the age of 17, 50% having yet to reach that stage; but some 10% of normal boys have yet to achieve full maturity at the age of 19 and a half years whilst 3% will have achieved this at the age of 16. For girls, the 50th percent age is around 15 years, 3% having 'adult' maturity at 14.

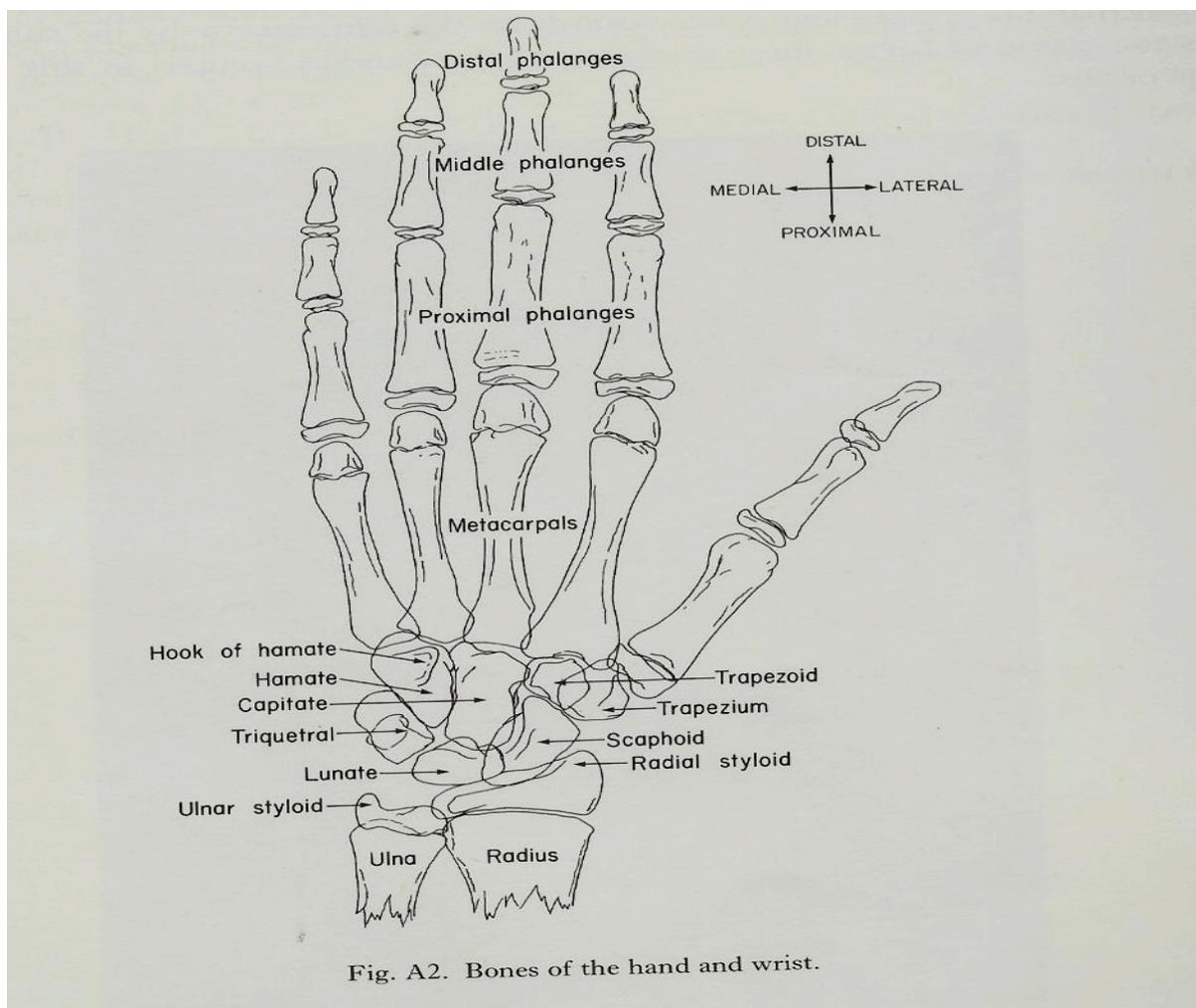
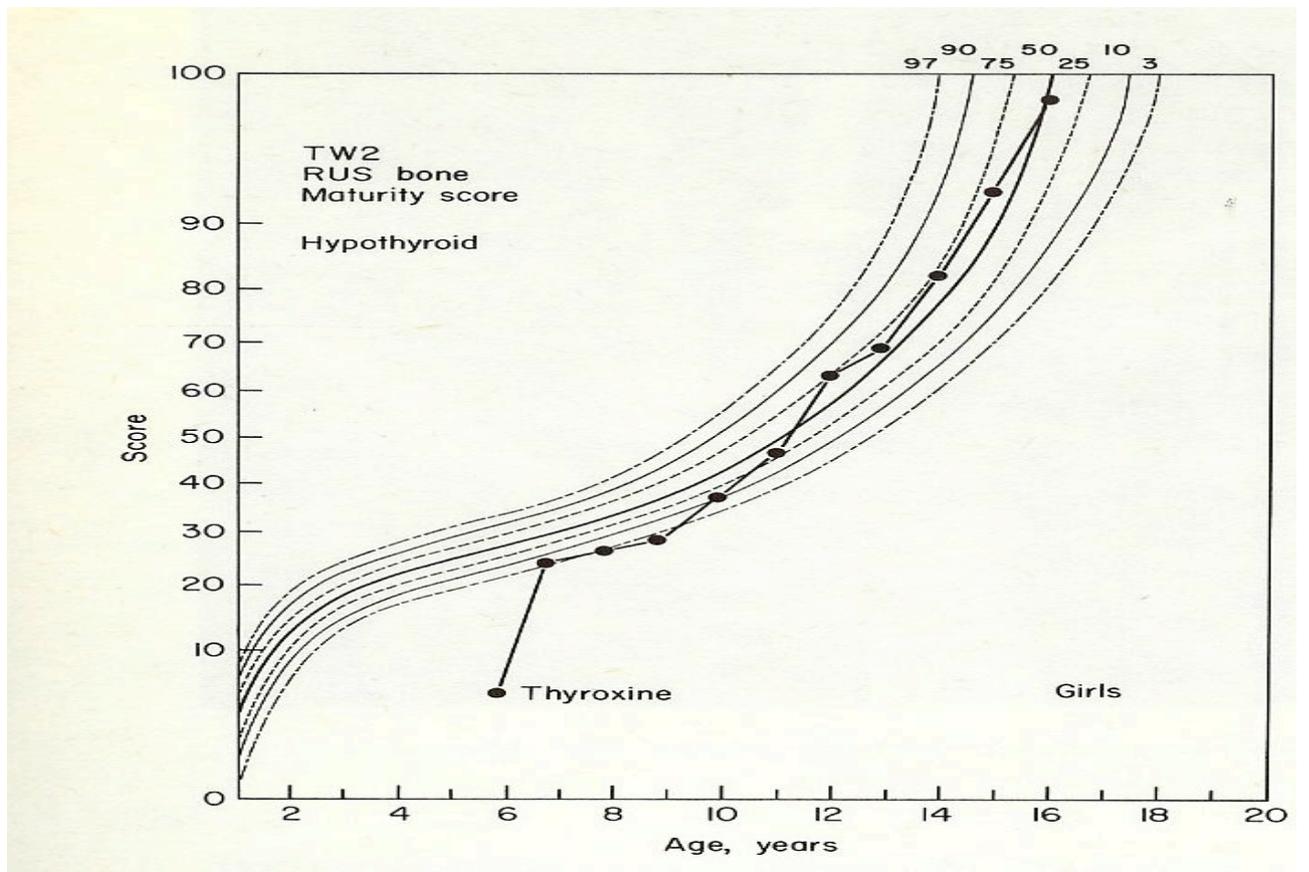
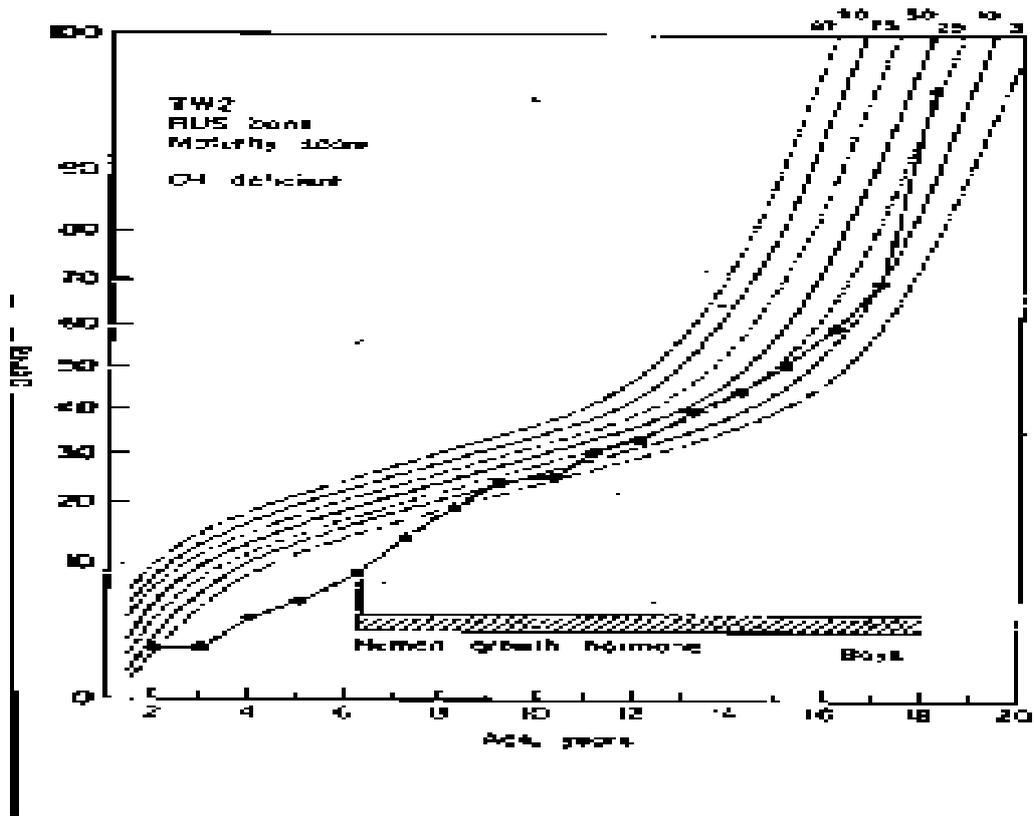


Fig. A2. Bones of the hand and wrist.



The charts also show the trajectories of bone development in a girl found to be suffering from an underactive thyroid gland and in a boy with growth hormone deficiency. At the age of 6 years, she had grossly retarded bone development, but as treatment was introduced, her bone 'age' rapidly increased, and with titration of the dose of treatment against growth and bone development, she achieved final average adult height with normal bone maturity. A similar effect is seen in the Boy's chart showing the trajectory of a boy with growth hormone deficiency. These are examples of the major effects that endocrine diseases can have on growth and bone development, and demonstrate the subsequent dissociation between chronological age and bone maturity thereby reinforcing the key point that bone maturity does not necessarily equate to chronological age.

Of much greater relevance to the case of John Ndollu, the charts show the very substantial range of normality for the speed of bone development during the adolescent years, reinforcing the assertion that the method is inaccurate and not fit for the purpose proposed. These points are rarely raised by those advocating for radiology in the context of asylum claimants.

Commentary on the interpretations by Drs Whisson and Low

Dr Whisson states that the growth plates are all fused and the bones fully developed and consistent with a Greulich and Pyle bone age of 19. ***The crucial point, however, is that this does not mean that the subject's chronological age must also, and inevitably, be at least 19.***

Dr Low asserts that John Ndollu is adult, and provides a statistical proposal to validate his conclusion. However, his conclusion has to be challenged on the basis of his failure to understand the statistical background to the Greulich and Pyle data he refers to.

I have taken the trouble to consult Professor Tim Cole, one of Europe's foremost biostatisticians in the field of children's growth on Dr Low's analysis and interpretation, and with his permission, his comments are added to my report as an Appendix.

It can be seen from this that Professor Cole emphasises that :

'The use of the Atlas in this way is inappropriate and the conclusions drawn are wrong '

He also states:

The average age of 19 years for a mature x-ray as used by Dr Low is itself meaningless, since it can be seen at any age between 15 and 95+ years. What is needed is the mean *age of attainment* of a mature x-ray, i.e. the mean age at which the x-ray becomes mature. This age will be earlier by definition (the earliest age it can be seen in the individual), which will increase the probability of

being <18 years. However it is not given in the Atlas, nor is it even considered there. It is important to realise that the Atlas's purpose was to estimate bone age in growing children. Greulich and Pyle had no interest in children whose x-rays were mature, as they could not ascribe a bone age to them. So they excluded such children from their calculations.

And:

There are two important factors that affect the mean chronological ages attributed to the bone ages in the G-P Atlas – the secular trend to earlier maturity, and ethnic differences in the rate of maturation. The reference sample for the Atlas was local and relatively privileged US children in the 1950s. Since then with the secular trend they have become relatively less mature.....

TW3 is a sophisticated bone scoring method that rates individual hand and wrist bones, and hence is both more accurate and up-to-date than Greulich-Pyle.

He examines the statistical basis for bone maturity using the most recent data incorporated in the TW3 method and says that:

The TW3 manual ² discusses the range of ages of bone maturation based on radius, ulna and short (i.e. finger) bones. Table 8 (page 21) gives the 97th centile for age of attainment in boys as 15.1 years, i.e. 3% of boys have reached skeletal maturity by then. The corresponding 90th and 75th centiles are 15.8 and 16.7 years. Extrapolating to the 50th centile gives the median age as about 17.6 years, so that half of all boys have reached skeletal maturity by this age. The corresponding centiles at 18 and 19 years are around the 40th and 15th centile respectively, so about 60% of boys are mature by 18 and 85% by 19. Thus G-P probably chose 19 years as most males are mature then.

He concludes by saying:

In conclusion, the Greulich-Pyle Atlas was not designed to assess age in young people who are skeletally mature, and it should not be used for that purpose. A mature hand-wrist radiograph is compatible with any age from 15 years upwards, and more than half of boys will have reached maturity before the age of 18 years.

I agree unreservedly with Professor Cole's comments leading me to conclude that:

It is unsafe to use the flawed interpretations of the X-ray to judge John Ndollu to have had a chronological age of 19 or greater when the X-ray was taken.

The case exposes further issues that I should like to refer to.

The international context of age assessment in migrants

The unprecedented increase in human migration worldwide generates major challenges for countries in managing the influx of individuals seeking refuge, asylum or better economic prospects.

Of special concern is the increase in the number of unaccompanied minors, often deeply traumatised from their experiences that led them to be separated from their families. Adult migrants and traffickers exploiting their migration have learned that children are given special status that demand full protection of benefits and opportunity. As a consequence, Border Agencies and their staff have a serious practical problem in how to decide who is a child and who is adult, this being made more difficult by many individuals not having official documents to confirm age. Even when documents are available, a culture of disbelief in immigration agencies, perhaps fuelled by public or political opinion, can lead to rejection of a claim to be a child.

The assessment of age in undocumented migrants is currently one of the most difficult and politically explosive issues around the migration of children being discussed by EU countries and their border agencies.

It is my expert opinion from my extensive involvement in debating asylum processes in the UK and Europe that:

The implications of age assessment are so serious to the individual and to society that there must be confidence that the process is transparent (having been subjected to rigorous professional and public scrutiny), ethical, consistent with international Human Rights legislation, and above all, grounded in an understanding of the difficulties and lack of precision inherent in the methods available. Staff performing assessments should be independent of budgetary or custodial responsibility for care provision, trained and accredited to a high level of competence, and supported by practical guidance and rigorous protocols from Government Immigration Directorates that allow the generation of a definitive record. These should include video recordings that can be audited thereby providing clear evidence of how a conclusion was reached, should that conclusion be challenged in the courts.

Question

Is the approach to age assessment in Australia consistent with these principles?

The practical challenge

The key practical challenge, however, is how to assess the age of a person who claims to be a child yet has no reliable documents to prove it.

It is important to emphasise that John Ndollu is not, strictly speaking, an *undocumented* migrant – there is evidence of date of birth coupled with affidavits. It might well be that the Prosecution Service and Police do not believe the validity of the evidence, and this culture of apparent disbelief must deserve exposure and public scrutiny.

Questions

Why has the documentary evidence been over-ridden in favour of an X-ray report, and is this a consistent practice in such cases?

Governments want a ‘scientific’ method that will tell the precise chronological age of the person. **But, no such method exists.** The fundamental importance of this statement cannot be overemphasised, and the reasons for this assertion are to be found in my accompanying report.

It is recommended that the fact that no scientific method exists that will give precise chronological age should be repeatedly emphasised to government and officials and to the Courts, and that a judgement should not be made on the basis of one method or the conclusions of one practitioner.

Question:

Has this reality been recognised and its implications subjected to scrutiny by policy makers and professional staff in Australia?

Approaches to age assessment

The different methods used in age assessment are reviewed in my accompanying report, but from analysis of methods in use across the EU, the following broad categories of approaches can be proposed:

1. Non-medical, incorporating evaluation of existing documentation, interviews and analysis of narrative
2. Medical, including physical examination, anthropometry, analysis of sexual development, mental and emotional development and imaging of bones and/or teeth
3. Combined, bringing together aspects of 1 and 2, but excluding radiology
4. Future developments

Questions

Has the use of Radiology for age determination in Australia been exposed to rigorous public, ethical and professional scrutiny? If not, what should be done to ensure that it is?

In view of the extent of international ethical concern, has its use been sanctioned or supported by the courts and human rights legislators?

The use of dental X-rays to assess 'Age'

John Ndollu has not been subjected to dental X-rays, but for completeness, it is important to state here that this approach does have followers and advocates for use in some EU countries, but similar vigorous objections as for skeletal radiology have challenged their use.

Current practice in the UK

Individuals claiming refuge might experience a requirement to assess age in several circumstances. First, an initial assessment on whether the individual is likely to be a child or not; second, as part of the formal screening process to assess the validity of the claim, and third, where there is a dispute over the conclusion.

In the UK, an initial assessment is made at the start of the screening process by social workers. If the ***physical appearance, narrative and overall demeanour very strongly suggest that the person is 'significantly' over the age of 18, the applicant is normally treated as an adult.*** If thought close to 18, then they are treated as a minor unless and until they are subsequently judged to be an adult through an age assessment process.

In the light of judgements by the courts in a disputed case in the London borough of Merton, the concept of 'Merton Compliance' has been introduced. This means that two trained social workers are expected to perform an assessment of the applicant's physical appearance, social development, their account of the family life and educational history, supplemented wherever possible by any available documentary evidence. If this suggests that the individual is under the age of 18, then this is usually accepted by the UK Border Agency in assessing the claim, unless there is credible evidence to the contrary.

In practice, it is easily possible to see that a toddler is a young child; likewise, a man with grey hair and beard is unlikely to be a child. The real difficulty relates to individuals during adolescence and early adulthood where there is a very substantial range of the normal speed of physical and sexual development, coupled with cognitive development.

It is important to remind practitioners and lawyers of our own schooldays – at the age of 16, many children in the class for the year had the appearance of full maturity in or in excess of 18, yet others still looked as though they were 12. This range of appearance and demeanour is entirely normal and to be expected in any population of adolescents.

Mr John Ndollu had already been assessed to be a child by the immigration officers, and was receiving services and support on that basis.

Non-radiological methods of imaging bone development.

Because of the ethical limitation in using X-rays, the use of non-ionizing radiation methods is intuitively attractive. FIFA has explored the use of magnetic resonance imaging (MRI) in under-17 year football tournaments.

Although these methods are claimed to show greater inter-observer reliability, emerging evidence suggests that they underestimate bone maturation when compared to X-rays and the same reservations must apply in that there will also be very considerable variation in the MRI-assessed speed of bone development during adolescence and age of attainment of maturity.

It has to be concluded that much further work must be done to validate the MRI approach to assessing age in normal populations before considering their use as a routine method for asylum seekers. Furthermore, the technology demands expensive equipment and specialist expertise limited to few locations.

Finally, because of its low cost, freedom from radiation, portability and ease of use, commercial interest has been expressed in the use of ultrasound for wrist bone development, but questions also exist regarding reliability and reproducibility, together with the same concerns over the effects of ethnicity, coupled with the range of normality for bone fusion. To date, there is no good information on the application of this technique to age assessment of asylum seekers.

It has to be reiterated that at present there is no method using any source of imaging that will give immigration staff and politicians a 'scientific' answer to determining the precise age of an individual seeking refuge.

For these reasons, I and others propose that:

Multi-professional assessment – a 'holistic' approach - involving a team of social workers, educationists, paediatricians and psychologists working in specialised Age Assessment Referral Units or within the existing structures for child protection would seem to be a pragmatic way forward in order to obtain a consensus decision on age.

This concept is under active exploration in England and in other EU countries at present, and rigorous academic research needs to be done to test its reliability and validity.

Overall conclusions

- 1) The case of John Ndollu exposes aspects of the current process of assessing age in Australia that should cause grave concern
- 2) Serious injustice is possible by a decision being driven by using a method involving wrist X-ray which has been rejected elsewhere, and which is unethical, not fit for purpose proposed, inaccurate and potentially unlawful.
- 3) The use of radiology deserves vigorous public, professional and ethical scrutiny
- 4) There appears to be a culture of disbelief in not accepting documentary evidence in the Prosecution and Police services. This should be challenged.
- 5) Australian society, professional organisations and its Courts need to define as a matter of urgency which methods of age assessment are acceptable, what limits of uncertainty are valid, and how a consensus can be reached in individual cases.

I recommend from the evidence I have seen:

- An urgent need to expose current practices to public scrutiny, ideally by giving Children's Commissioners or other statutory bodies the power given to the English Children's Commissioner to enter premises where children are cared for, unannounced if necessary, to interview children in private, if the child agrees, and to witness the day to day processes involved in the screening and age assessment of individuals claiming to be children.
- Statutory and regulatory bodies must decide, aided by expert input from medical ethicists and human rights practitioners, whether Australia will continue to promote radiology for administrative purposes

- Urgent credible and independent research should be funded to explore the development of the holistic multi-professional approach advocated in this commentary

A handwritten signature in black ink, appearing to read 'Al Aynsley-Green', with a long horizontal flourish underneath.

Professor Sir Al Aynsley-Green

24th June 2011

Appendix

Use of the Greulich-Pyle radiographic atlas for bone age assessment

Tim J Cole PhD ScD Hon FRCPCH FMedSci

Professor of Medical Statistics

UCL Institute of Child Health, London WC1N 1EH, UK

Dr Vincent Hock Seng Low used the Greulich-Pyle Radiographic Atlas ¹ to estimate the bone age, and hence the likely chronological age, of Mr JN. He observed that the subject's hand-wrist radiograph matched the Atlas radiograph of a 19-year-old, and inferred that on average his chronological age would be 19 years. To assess the uncertainty around the mean he used the standard deviation (SD) of 15.4 months given in the Atlas. He estimated probabilities of the subject's chronological age being less than a series of given ages, for example a probability of about 22% of his being ≤ 18 years old. His conclusion was "In my opinion the subject of the x-ray had reached skeletal maturity and was therefore probably 19 years or older at — — — when the x-ray was taken."

The use of the Atlas in this way is inappropriate and the conclusions drawn are wrong. The probability of the subject's being < 18 years old exceeds 22% and is actually more than 50%, though the Atlas lacks the information needed to say by how much.

Dr Low's calculation of probabilities from the mean and SD is correct, but it relies on the mean and SD being appropriate, and neither of them are. True, the Atlas radiograph of a skeletally mature (adult) hand-wrist x-ray is labelled as age 19 years, but this is only for convenience, coming as it does at the end of a series of x-rays for successive ages in childhood. In no sense is 19 years the average age of an mature radiograph – it can be seen in children as young as 15 years and throughout adult life. It is in fact the age when most males have reached skeletal maturity, as is shown below.

To give an idea of the imprecision of the age estimate, the Atlas includes two tables giving the mean and SD of bone age for groups of children of known chronological age. The first table (Table III, page 51) is for children from the Brush Foundation study, where a large number of children were each assessed once. The final age group in the table is 17 years, where the mean bone age was 206.21 (SD 13.05) months. The second table (Table V, page 55) is for children studied longitudinally by Dr Stuart at the Harvard School of Public Health. Here the final age in the table is again 17 years, and the mean bone age was 206 (SD 15.4) months, this being the SD that Dr Low used.

There are two striking things about these tables. The first is that the final age group is no older than 17 years. This shows that there were too few children with older bone ages to be included, i.e. that most children past 17 years had mature x-rays. Thus there were many children aged <19 years with mature x-rays.

The second point is the numbers of children in each age group, shown here:

Age ->	12	13	14	15	16	17
Brush	165	175	163	124	99	68
Stuart	64	66	65	65	65	60

In the Brush Foundation study the numbers fell off steeply after age 14, showing that children with immature x-rays in those age groups were progressively less common. In Stuart's longitudinal study where the numbers were fairly constant across age, even here there were drop-outs at 17 years whose x-rays were clearly mature.

So the SD of bone age that Dr Low used is inappropriate in two respects: it is based on boys (a) aged 17 not 19 years, and (b) with immature not mature x-rays. Thus his application of the SD to a 19-year-old with a mature x-ray is quite wrong.

The average age of 19 years for a mature x-ray as used by Dr Low is itself meaningless, since it can be seen at any age between 15 and 95+ years. What is needed is the mean *age of attainment* of a mature x-ray, i.e. the mean age at which the x-ray becomes mature. This age will be earlier by definition (the earliest age it can be seen in the individual), which will increase the probability of being <18 years. However it is not given in the Atlas, nor is it even considered there. It is important to realise that the Atlas's purpose was to estimate bone age in growing children. Greulich and Pyle had no interest in children whose x-rays were mature, as they could not ascribe a bone age to them. So they excluded such children from their calculations.

There are two important factors that affect the mean chronological ages attributed to the bone ages in the G-P Atlas – the secular trend to earlier maturity, and ethnic differences in the rate of maturation. The reference sample for the Atlas was local and relatively privileged US children in the 1950s. Since then with the secular trend they have become relatively less mature, and on average are similar in age to the ratings given in the TW3 manual.² TW3 is a more recent and sophisticated bone scoring method that rates individual hand and wrist bones, and hence is both more accurate and up-to-date than Greulich-Pyle.

The TW3 manual ² discusses the range of ages of bone maturation based on radius, ulna and short (i.e. finger) bones. Table 8 (page 21) gives the 97th centile for age of attainment in boys as 15.1 years, i.e. 3% of boys have reached skeletal maturity by then. The corresponding 90th and 75th centiles are 15.8 and 16.7 years. Extrapolating to the 50th centile gives the median age as about 17.6 years, so that half of all boys have reached skeletal maturity by this age. The corresponding centiles at 18 and 19 years are around the 40th and 15th centile respectively, so about 60% of boys are mature by 18 and 85% by 19. Thus G-P probably chose 19 years as most males are mature then.

In conclusion, the Greulich-Pyle Atlas was not designed to assess age in young people who are skeletally mature, and it should not be used for that purpose. A mature hand-wrist radiograph is compatible with any age from 15 years upwards, and more than half of boys will have reached maturity before the age of 18 years.

1. Greulich WW, Pyle SI. Radiographic atlas of skeletal development of the hand and wrist. 2nd ed. California: Stanford University Press; 1959.
2. Tanner JM, Healy MJR, Goldstein H, Cameron N. Assessment of skeletal maturity and prediction of adult height (TW3 method). 3rd ed. London: WB Saunders; 2001.