Emery-Dreifuss muscular dystrophy: linkage to markers in distal Xq28


Abstract
Emery-Dreifuss muscular dystrophy (EMD) is characterised by (1) early contractures of the Achilles tendons, elbows, and postcervical muscles, (2) slowly progressive muscle wasting and weakness with a predominantly humero-peroneal distribution in the early stages, and (3) cardiomyopathy with conduction defects and risk of sudden death. Inheritance is usually X linked recessive but can be autosomal dominant. Family linkage studies have mapped X linked EMD to the distal long arm of the X chromosome. Precise genetic localisation has been hampered by the rarity of the condition. Published linkage data are only available for 13 EMD families showing unequivocal X linked inheritance and only a minority of these have been comprehensively typed for Xq27-qter markers. We report here three new families with X linked Emery-Dreifuss muscular dystrophy studied with DNA markers from Xq27-qter and three previously published families typed for additional markers.

Patients
Three new families with X linked Emery-Dreifuss muscular dystrophy were studied. The family pedigrees are shown in the figure.

FAMILY 1
Family 1 (EMD Consortium family 17) is from Scotland. All subjects contributing to the linkage study were examined in their homes by JRWY and the results of previous investigations were reviewed. The diagnosis of EMD was based on the findings in III-1 who presented at 4 years of age with toe walking and distal lower limb weakness. By the age of 11 years he had contractures at the elbows with some humeral weakness and limitation of spinal flexion. The weakness progressed slowly over the next 20 years becoming predominantly proximal in the lower limbs while remaining mainly humeral in the upper limbs. Complete heart block was diagnosed at 36 years of age and treated by insertion of a cardiac pacemaker. At 43 years of age he was just able to walk with support. IV-4 showed a similar course with early contractures affecting the Achilles tendons and elbows and limitation of neck flexion apparent on examination at 18 years of age. He had atrial tachycardia with varying atrioventricular heart block. IV-11 had an abnormal gait from 3 years of age. At 6 years of age he was recorded as having a scapulo-peroneal pattern of weakness with ankle dorsiflexion being particularly weak. He required lengthening of his Achilles tendons at the age of 9 years. IV-8 was examined at 8 years of age and was found to have mild weakness of hip flexion and extension, knee flexion, and ankle dorsiflexion. In all four of the affected subjects the muscle involvement was bilateral and approximately symmetrical. None showed calf hypertrophy. Intellect was normal. Serum creatine kinase varied from normal to moderately raised, the highest level
Pedigrees of EMD families 1, 2, and 3. Affected males are shaded and obligate carrier females are indicated by a central dot.

Family 1

Family 2

Family 3

FAMILY 3

Family 3 from Turkey was evaluated by FD. The diagnosis of EMD was based on the findings in the three affected males II-4, II-5, and III-20 of (1) childhood onset of slowly progressive muscle wasting and weakness with a scapulohumero-peroneal distribution, (2) early contractures of the Achilles tendons, elbows, and neck muscles, and (3) cardiac conduction defects (necessitating cardiac pacemaker insertion in II-4 and II-5). Serum creatine kinase levels were normal or mildly raised. A muscle biopsy in II-5 showed dystrophic changes. The pedigree shows unequivocal X linked inheritance. Full details of this family will be published elsewhere.

Methods

Blood samples were obtained from available family members, DNA extracted by routine methods, and DNA polymorphisms analysed by Southern analysis or the polymerase chain reaction using standard protocols. The families were typed for the DNA markers DXS304 (probe U6:2/TaqI restriction digest), DXS52 (Stu1-4/TaqI), DXS15 (DX13/BglIII), RGGP (HS7/SacI), F8G (p114.12/Bell), and DXS115 (767/BstXI) as detailed elsewhere.13

Additional linkage data were obtained by completing the typing of the above markers in two families we have reported previously9 (EMD Consortium families 5 and 6ª) and in a

being four times the upper limit of normal. An electromyogram (EMG) in III-1 was myopathic. Muscle biopsies in III-1 and IV-11 supported a diagnosis of muscular dystrophy. None of the females in the family had evidence of muscle weakness. The unaffected male subjects IV-5, IV-9, and IV-10 were all asymptomatic at ages 20, 21, and 22 years respectively with normal cardiovascular and neurological examinations. Their serum creatine kinase measurements were normal except for IV-9 who had a level three times the upper limit of normal on first testing, but a normal level when repeated a few weeks later. None of the family was colour blind.

inserted. Examination at the age of 31 years showed a waddling gait with lumbar lordosis. There were contractures of the elbows, ankles, and postcervical muscles. There was wasting and weakness most marked in the humeral, pelvic, and peroneal muscles. Tendon reflexes were absent. Spinal flexion and extension were weak. There was no calf hypertrophy. Intellect was normal. Serum creatine kinase was four times the upper limit of normal. EMG was myopathic. Muscle biopsy showed myopathic changes. III-4 suffered a similar but milder pattern of disease. Cardiological assessment at 21 years of age showed first degree heart block and partial right bundle branch block. A cardiac pacemaker was inserted. Examination at the age of 25 years showed a waddling gait with marked lumbar lordosis. There were contractures of the elbows and postcervical muscles. There was weakness of the humeral muscles. In the lower limbs there was marked peroneal weakness and lesser involvement of proximal muscles. Tendon reflexes were absent. Spinal flexion and extension were weak. There was no calf hypertrophy. Intellect was normal. Serum creatine kinase was five times the upper limit of normal. Muscle biopsy showed myopathic changes. II-2 walked on his toes from early childhood with an abnormal gait said to resemble that of the index case. In adult life he complained of episodes of chest pain and at 28 years of age he unexpectedly collapsed dead. If he was indeed affected by EMD then the pedigree shows X linked inheritance.
third family reported by Paquis et al\textsuperscript{a} (EMD Consortium family 912).

All six families studied meet the diagnostic criteria drawn up by the EMD Consortium for families using in linkage studies in X linked EMD.\textsuperscript{12} The clinical features in four of the families (EMD Consortium families 5, 6, 9, and 17) were reviewed at the European Workshop on EMD (1991) and accepted as meeting these criteria.\textsuperscript{12}

Linkage data were analysed using the computer programmes LIPED\textsuperscript{14} and LINKMAP\textsuperscript{15} for two point and multipoint analyses respectively. Confidence intervals were obtained by taking values of the recombination fraction corresponding to a lod score one unit less than the maximum.\textsuperscript{16} Published multiple pairwise data were analysed with the computer programme MAP\textsuperscript{17} using the corresponding to 0:35.

Results

Two point lod scores between EMD and marker loci are given in the table. No recombinants were observed with RGCP (HST7), F8C, or DXS115 (767). EMD Consortium family 5 showed a recombinant between EMD and DXS52 (Sti4-1) as we have previously reported\textsuperscript{6} with two affected brothers having different restriction fragment patterns at this locus. They had the same marker patterns for DXS15 (DX13) and F8C but their obligate carrier mother was dead and could have been homozygous at these loci. In the present study these results were confirmed on repeat blood samples and additional typing showed that they were also recombinant for the more proximal marker DXS304 (U6.2) but had the same marker patterns for RGCP and DXS115. Consortium family 9 showed a recombinant between EMD and DXS15 as previously reported\textsuperscript{a} with two affected brothers having different restriction fragment patterns at this locus. More proximal markers were also recombinant, DXS52 was uninformative, and F8C was non-recombinant. In the present study these results were confirmed on repeat blood samples and additional typing showed that RGCP was non-recombinant.

For the multipoint analysis we used the marker order DXS304 (proximal), DXS15, DXS52, RGCP, F8C, DXS115 (distal) with recombination fractions of 0-09, 0-03, 0-02, 0-03, 0-02, respectively, calculated by multiple pairwise analysis of published linkage data.\textsuperscript{16} This order is consistent with recent physical mapping data\textsuperscript{20} except that the order of DXS15 and DXS52 is not well established. The pairwise analysis provided weak support for DXS15 being the more proximal marker.

In the LINKMAP analysis the maximum location score was 38-5 with EMD coincident with F8C. This position was favoured by odds of 200:1 compared to a location between DXS52 and DXS15 and by odds exceeding 1000:1 compared to all locations proximal to these markers. If the order of DXS15 and DXS52 were reversed, the maximum location score was 38-8 with EMD coincident with F8C and this position was supported by odds exceeding 1000:1 compared to all locations proximal to DXS15. In the absence of recombinants it was not possible to determine order with respect to RGCP, F8C, or DXS115.

A second LINKMAP analysis incorporated published data for which haplotype information is available, taken from Thomas et al\textsuperscript{1972,2} family A of Romeo et al\textsuperscript{1988,6} and Cole et al\textsuperscript{1992} (EMD Consortium families 1, 2, 3, and 8). The maximum location score was 66-1 with EMD coincident with RGCP. This position was supported by odds of 120:1 compared to the next highest location score when EMD was coincident with DXS115. The odds against locations proximal to DXS52/DXS15 exceeded 10 000:1.

Discussion

The results presented here map the Emery-Dreifuss muscular dystrophy locus (EMD) close to the factor VIII coagulant gene locus (F8C) in Xq28 and are consistent with previously reported data. Until recently there was uncertainty about the order of markers in the vicinity of F8C but from the physical mapping data of Poustka et al\textsuperscript{20} it now seems that the most likely order is cen-DXS304-DXS52, DXS15-RGCP-F8C-DXS115-qter. Provided this order is correct, the recombinants reported previously\textsuperscript{9} and now confirmed and further characterised in this report map EMD distal to DXS15 (DX13) and DXS52 (Sti4). This is consistent with the recombinant with DXS52 and DXS15 identified by Hodgson et al\textsuperscript{a} and confirmed in a subsequent report.\textsuperscript{21} Taken together these data provide strong evidence for a distal location for the Emery-Dreifuss muscular dystrophy locus within a region estimated at 3 Mb from DX13 to the telomere.

A recombinant recently reported by Cole et al\textsuperscript{a} maps EMD proximal to F8C. This finding has been fully validated by clinical review of key family members, repeat blood sampling, and independent confirmation of the marker.
typing by a second laboratory. Conflicting data from another family apparently mapping 
EMD distal to F8C\(^{22}\) has recently been withdrawn on the basis of the clinical status of the 
relevant family members.\(^{23}\)

All the current data are therefore consistent in placing EMD between DXS15/DXS52 and 
F8C. This location is supported by odds of 120:1 in the LINKMAP analysis presented here incorporating published data for which haplotype information is available. This 
corresponds to a physical distance of approximately 2 Mb.\(^{20}\) Further family studies will be 
needed to confirm F8C as a distal flanking marker. Better localisation will also be dependent 
on having new markers from this interval so that flanking recombinants can be mapped 
precisely.

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